

Climate risk assessments for industry sectors and infrastructure sectors reveal challenges from interconnectivities, interdependencies across value chains, and the impacts of policy and regulations.⁵⁵ International dimensions include mechanisms such as price, material flows, movement of people and political stability, with specific emphasis on food security and geopolitical risks.⁵⁶

The complexity, uncertainty and ambiguity associated with climate risk point to a number of challenges and frontier issues for assessing the risks associated with climate change in a policy-based context. These include the issue of dealing with systemic risks, critical knowledge gaps regarding Earth system processes, and the complexity of societal responses – which could collectively lead to extremely challenging outcomes. Much of the uncertainty in climate change assessments is irreducible; this uncertainty should be treated as a source of actionable knowledge through its influence on the viability of different decision strategies. While the UNFCCC has framed climate risk in terms of dangers, risk assessment should evaluate both positive and negative aspects of change to support a balanced appraisal of alternative decision options. Other issues relate to risk assessment processes themselves, such as managing uncertainty and clarifying the hidden values assumptions of the risk analysts.⁵⁷

This section presents the case that it is time for a shift in the objectives and implementation of climate change assessments – from making what amounts to a general case for ‘action’ regarding eliminating fossil fuel emissions, to characterizing specific regional risks and vulnerabilities in a manner that helps people develop, select, carry out, and monitor actions that ultimately have greater benefits than costs.⁵⁸

10.3.1 How we have mischaracterized climate risk

“The global climate change debate has gone badly wrong. Many mainstream environmentalists are arguing for the wrong actions and for the wrong reasons, and so long as they continue to do so they put all our futures in jeopardy.” – philosopher Thomas Wells⁵⁹

The communication and handling of the climate change risk is strongly dependent on the way risk is conceptualized and described.

In the early 1980’s, the United Nations Environmental Program (UNEP) became bullish on the idea that fossil fuels would produce dangerous climate change. The prospect of eliminating fossil fuels was congruent with UNEP’s broader interests in environmental quality and world governance. At Villach, Austria, in 1985 at the beginning of the climate treaty movement, the policy movement to eliminate fossil fuels became detached from its moorings in the science – the rhetoric of precaution argued that we should act anyway to eliminate fossil fuels, just in case.^{60 61} This perspective became codified by the 1992 UN Framework Convention on Climate Change (UNFCCC) Treaty in 1992, the Kyoto Protocol in 1997 and the 2015 Paris Climate Agreement.

The fundamental presupposition of the UNFCCC climate treaties and agreements is that human-caused climate change associated with fossil fuel emissions is dangerous – natural climate variability and most other human impacts on climate were essentially ignored. There was an implicit assumption that warming was dangerous, ignoring any potential benefits. In attempting to build political will for the international agreements, the adverse impacts of fossil-fuel driven climate change were exaggerated – more frequent and intense severe weather/climate events, sea

level rise and many adverse ecosystem, health, economic and geopolitical impacts, with all of their complex causes, were conflated with fossil-fuel driven warming (Section 1.1).

The torquing of climate science and the manufacture of a consensus around human-caused climate change (Chapter 2) not only oversimplified the scientific and social challenges, but led to the adoption of a “predict then act” strategy to manage and control the climate. This strategy is based on the belief that climate change is a simple or tame problem, with science trumping all practical questions and conflicting values and purposes.

One of the biggest problems associated with climate change assessments is that there is no simple way to articulate danger associated with a warmer climate (Section 1.3). To circumvent this challenge, the problem of climate change has been reduced to one of CO₂ emissions, with the elimination of human-caused emissions as the primary strategy for dealing with the problem. This strategy ignores the fact that there is no precise link between CO₂ emissions and global mean surface temperature, owing to uncertainties in climate sensitivity to CO₂ (Section 7.2) and the poorly constrained natural variations of the climate system. An alternative approach focused on a specified “dangerous” surface temperature threshold.⁶² This approach also requires accurate accounting and projections of natural climate variability from solar variability, volcanic eruptions, and multi-decadal to millennial scale ocean variations (Section 8.2). An additional complication is that the temperature targets of 1.5 and 2.0 °C do not have a sound scientific basis as thresholds for danger (Section 1.3).

Further, the temperature-based approach of specifying a dangerous threshold ignores nonlinearities in the climate system. Climatic “tipping points” (Section 1.3), which have been described as “real critical thresholds,” do not all occur at the same temperature threshold. If

unknown climate tipping points exist that are associated with natural climate processes, there can be no certainty that the risk of climate catastrophe would be eliminated even if emissions fell to zero.⁶³

The end result of the way in which the IPCC/UNFCCC have characterized the climate change problem is that we are focused on meeting emissions targets that are arguably unachievable in the near term, rather than on obtaining a deeper understanding of the climate system and the broader causes of vulnerabilities of human and natural systems. Further, the slow incremental risks of warming have been mischaracterized as urgent, leading to rapid implementation of policies that are not only costly and suboptimal, but also arguably reduce societal resilience to weather and climate variability, whatever their causes.

The politics of international climate governance has produced systematic biases in the kinds of expertise and evidence that are deemed appropriate for consideration.⁶⁴ The UNFCCC and IPCC have characterized climate change as an environmental and economic problem, and geoscientists and economists have dominated the assessment and policy making process.

However, the issues with increasing CO₂ and warming are social, not environmental. The Earth has undergone geological periods of higher temperatures and atmospheric CO₂ concentrations, during which life thrived. Characterization of climate change as an environmental problem has downplayed the cultural and political dimensions of the issue.⁶⁵ In fact, many social scientists have argued that climate change is a values problem, and that the disciplinary constrictions imposed by the IPCC and UNFCCC have neglected many important insights arising from a wide range of expert and unaccredited sources.⁶⁶

Clarifying the multitude of values in play would help illuminate the ambiguity surrounding interpretations of climate risk. However, characterizing climate change as a values problem can also lead into blind alleys. Many environmentalists have moralized the climate change problem as a simple, righteous values choice: Are you for the planet or against it?⁶⁷ This moralizing neglects to understand that people engage in activities which are of value to them that happen to emit carbon as a byproduct.⁶⁸ Further, this narrow moralizing systematically excludes important ethical values, such as improving the lives of the billion people presently living in unacceptable poverty or protecting other aspects of the environment.⁶⁹

The end result is that after 30 years of the UNFCCC/IPCC, we remain fixated on the minutiae of greenhouse gas emissions levels and the abstract and impossible problem of constraining atmospheric CO₂ concentration – while ignoring natural climate variability and drastically simplifying the human impacts and responses. As long as the current situation prevails, the IPCC's assessments of anthropogenic climate change and the UNFCCC recommendations for action will remain seriously inadequate.

This fixation on global CO₂ levels alone as the problem and solution has led Norwegian risk scientist Terje Aven to conclude:

“The current thinking and approaches guiding this conceptualization and description have been shown to lack scientific rigour, the consequence being that climate change risk and uncertainties are poorly presented. The climate change field needs to strengthen its risk science basis, to improve the current situation.”⁷⁰

The UNFCCC is promoting a solution to an exceedingly complex, uncertain and ambiguous problem, without reference to wider ethical issues, and political and practical feasibility. We

have neglected to truly understand the problem and systematically and broadly evaluate the feasible policy space.

10.3.2 Reframing the assessment of climate risk

“[A] problem well put is half solved.” – American philosopher John Dewey⁷¹

Climate risks are exceedingly complex and scientific forecasts are subject to large uncertainties. As a result, there is deep uncertainty within climate change risk assessments. In the face of this deep uncertainty, a conventional predict-then-act approach is paralyzed by limits to prediction and lack of clarity regarding the potential consequences. Estimating the severity of the consequences based only on the potential economic losses ignores a series of impacts that are not easily quantified. In summary, we are far from a thorough assessment of full climate risk that would allow for efficient and targeted policies and support rational risk taking.⁷²

With this context, the risks from climate change need to be reframed more broadly, in context of advances in risk science.⁷³

There is an emerging literature on characterizing systemic risks from climate change. Systemic risks induced by climate change have three basic characteristics: 1) the wide scope of impacts, affecting a wide range of natural, economic and social systems; 2) the long duration of impacts; and 3) cumulativeness of these impacts that grow over time.⁷⁴

Assessment of systemic risk must account for the complexity of the climate system and the integrated effects on politics, the economy, society, culture, and the environment. Both emergency risks associated with extreme weather events and the slow creep of incremental risks have characteristics of systemic risk. Interaction of climate with a variety of processes of global

environmental change (both natural and human systems) represents an increased need to identify and characterize multiple stressors and their interactions across different scales.⁷⁵

How does a categorization of systemic risk actually help with the practical assessment of climate risk? Is such a diagnosis similar to a categorization of a problem as a wicked mess (Section 3.4), which may lead people to throw up their hands and shrug their shoulders? It is sometimes argued that a full assessment of the risks of climate change would be counterproductive, because the risks may be so large and the solutions so difficult that people will be overwhelmed with a feeling of helplessness, and will look the other way. However, rather than stymieing a solution, such categorizations help identify situations where simplistic solutions won't work and suggest paths that may lead to partial solutions and reductions in vulnerability.

There are a number of strategies that can be helpful for assessing systemic risks. These include portraying the full range of extreme future scenarios (global and regional), including extreme weather and climate events and worst-case scenarios (Chapters 8, 9). These scenarios can be used to drive narratives of danger and to stress test social and infrastructure systems. It is important to differentiate between acute impacts associated with extreme weather events versus incremental risks that develop over time, based on different latent periods and manifestations. *Forensic analysis of previous disasters and their complex effects can provide important insights in developing scenarios of systemic risks.*

Judgments of intolerable risks from climate change relate to mistakenly conflating the slow creep of global warming (an emerging risk) with consequences from extreme weather and climate events (emergency risks) and concerns about inequitable risk exposure to poorer populations. Removing the risks associated with the most extreme weather and climate events from the

consequences of global warming diminishes the perceived urgency for reducing fossil fuel emissions. The poorest populations would benefit far more from access to grid electricity and help in reducing vulnerability from extreme weather events, than from reductions to the amount of CO₂ in the atmosphere. Bjorn Lomborg, False Alarm

The uncertainties and complexity of the forces driving the social, biological, and physical dimensions of climate change ensure that we will most likely be surprised by the outcomes. However, there are several features of the climate problem that suggest that climate change related risks will increase in the future. These factors are:⁷⁶

- There is a substantial time lag between the emission of greenhouse gases and the related impacts, and the link to many impacts is not yet fully understood.
- Science is unable to predict long-term impacts accurately enough to provide a strong signpost for action.
- There is large heterogeneity in historical, current and expected future emissions among countries and sectors, and there is no single culprit.
- Variance and heterogeneity of climate related hazards and benefits are large, and winners and losers may change over time.
- There is large heterogeneity in vulnerability among countries, sectors and ecosystems.

The question of intergenerational equity is of special importance for emerging risks, owing to the lag between the emissions of greenhouse gases and the expected occurrence of the damage. There is no simple way to decide what duty of care we owe to future generations, but the IPCC's

socioeconomic pathways for the 21st century all have the world being better off by 2100, even under the most extreme emissions scenarios.

A key to securing meaningful action to reduce climate change risk is to clearly separate the incremental, emerging risks associated with long-term changes in average conditions—which can be addressed to some extent in the long term by reducing greenhouse gas emissions—from the emergency risks associated with extreme weather and climate events, which need to be addressed in both the present and future climate. Any assessment of climate risk needs to approach these two kinds of risk differently, depending on the nature of the decisions it aims to inform.

Once the incremental risks are separated from the emergency risks, the perception of urgency in reducing emissions is diminished. It becomes far more important to develop strategies for managing atmospheric greenhouse gases in a way that supports a transition that does not have adverse impact on security, the economy, industry and agriculture. The challenges for risk assessment are then to identify transition risks associated with proposed solutions to mitigate the rising atmospheric CO₂ content.

At this point, assessing the transition risks of eliminating fossil fuels is arguably more important than attempting to refine our assessments of the deeply uncertain incremental risks associated with fossil fuel emissions. Consequences of the transition are associated with a fairly solid knowledge base, leading many people to be more concerned about transition risks than they are about the more uncertain risks from climate change itself that are associated with a far weaker knowledge base.^{77 78 79}

Assessments of emergency risk associated with extreme weather and climate events generally focus on event type, sectoral impacts or regional assessments. Too many of these assessments are seemingly intended to build political will for eliminating fossil fuel emissions rather than conducting a serious assessment of emergency risk including systemic aspects.

A laudable example of weather emergency risk assessment relates to the ARkStorm scenario described in Section 9.4.2, related to extreme winter flooding in central California.⁸⁰ The state of California's ShakeOut Earthquake Scenario to support preparedness for a major earthquake demonstrated how postulating a hypothetical but plausible catastrophe provides a basis for better examining the interdependencies in social structure and infrastructure and expose choke-points and vulnerabilities.⁸¹ The ARkStorm risk assessment project engaged emergency planners, businesses, universities, government agencies, and others. Following a thorough development of the storm scenario and its direct impacts on inundation and landslides, they assessed secondary impacts on highways, electricity systems, wastewater treatment, water supply, dams, levees, telecommunications, agriculture, buildings, evacuation and sheltering strategies, business interruption, truck transport, and environmental and health issues associated with hazardous materials. The ARkStorm scenario and risk assessment informed community decision-making and is helping communities increase their resilience to severe California winter storms.⁸²

In assessing emergency risk from extreme weather/climate events, there are some key principles to follow:⁸³

1. Emergency risk from extreme weather/climate events is dominated by plausible worst-case events. Looking at extreme event data back to 1950, and calculating return periods, isn't useful here. Global climate models are of no direct use for

extreme event scenarios. Of the three extreme events selected in Section 9.4, the Florida hurricane scenario was based on data from 1935, the ARkStorm scenario was based on data from 1861/62, and the south Asian monsoon failure was based on data from 1756-1768 – the latter two cases were informed not only by historical records but also by paleoclimate reconstructions.

2. Consider all events, even if their probability of occurrence in a particular location is low. The low probability/high impact events, provided that the events are judged to be plausible or have occurred in the past, are associated with the greatest risks. Nevertheless, the cumulative impact of weaker events can also be significant.
3. Be holistic. Account for all relevant factors, as far as possible – including human behavior and the complex interactions between different parts of a system. Evaluate both direct and systemic risks across the relevant time and space windows appropriate to the decision process.]
4. Assess the current risk from weather/climate extremes, based on historical extreme events and today’s societal vulnerabilities. Additional scenarios can be created with incremental effects from global warming.

Commented [MJ7]: Take a holistic view. Account for all relevant factors, as far as possible – including human behavior and the complex interactions between different parts of a system. Assess systemic risks, as well as direct risks. Assess risks across the full range of space and time affected by the relevant decisions.

The seemingly overwhelming challenge of climate risk assessment and the associated political conflicts becomes more tractable by separating the incremental, emerging risk from the emergency risk associated with weather/climate extremes. By regionalizing risk governance, the management approach does not depend on an impossible global agreement for a dubious “perfect” solution that requires moral and political coercion. The regional approach offers a feasible pathway that respects the existing interests and values of the human beings concerned.

This approach works within our existing political institutions (no need for a global government) and offers transparent arguments for action within our present valualational framework, rather than requiring us all to assume a new and narrow set of values.⁸⁴

10.3.3 Climate change versus COVID-19 risk

“There is no power for change greater than a community discovering what it cares about” – writer Margaret Wheatley⁸⁵

The outbreak of the COVID-19 pandemic in the end of 2019 has generated or contributed to a series of interconnected financial, societal, and political crises on a global scale. This has triggered comparative studies of systemic risks of pandemics and climate change, which share many commonalities despite obvious differences.⁸⁶

Both pandemic and climate risks are systemic, in that their impacts propagate rapidly across an interconnected world. Both COVID-19 and climate change risks are nonstationary, with past probabilities and distributions of occurrences rapidly shifting and proving to be inadequate for future projections. Both risks are nonlinear, in that their socioeconomic impact grows disproportionately and even catastrophically once certain thresholds are breached (such as hospital capacity to treat pandemic patients). Both COVID-19 and climate change are risk multipliers, that highlight and exacerbate hitherto untested vulnerabilities inherent in the financial, energy, food and healthcare systems and the overall economy. Both risks affect disproportionately the world’s most vulnerable populations.⁸⁷

However, the timescales of both the occurrence and the resolution of pandemics and climate hazards are different. Pandemic risk is measured in weeks, months, and years; climate risk is

measured in decades and centuries. A pandemic presents imminent, discrete, and directly discernable dangers. By contrast, the risks from climate change, are gradual, cumulative, and distributed, manifesting themselves over time and in spatially heterogeneous way.⁸⁸ The primary difference between the pandemic and climate hazards is that the salience of the threat and perceived urgency of dealing with it.⁸⁹

¹ Graham Burchell and François Ewald, "Insurance and Risk," in *The Foucault Effect: Studies in Governmentality ; with Two Lectures and an Interview with Michel Foucault* (Chicago, IL: Univ. of Chicago Press, 1991).

² Joshua P. Nudell, "An Ancient Greek Approach to Risk and the Lessons It Can Offer the Modern World," *The Conversation*, February 22, 2021, <https://theconversation.com/an-ancient-greek-approach-to-risk-and-the-lessons-it-can-offer-the-modern-world-154139>.

³ Daniel J. Rozell, "Values in Risk Assessment," in *Dangerous Science: Science Policy and Risk Analysis for Scientists and Engineers* (London, UK: Ubiquity Press, 2020), 29-56.

⁴ "Resources," Society for Risk Analysis, accessed May 24, 2022, <https://www.sra.org/resources/>.

⁵ Orson Scott Card, *Shadow of the Hegemon* (New York, NY: Tor, 2009).

⁶ Ortwin Renn, *Risk Governance Coping with Uncertainty in a Complex World* (London, UK: Routledge, 2008).

⁷ Terje Aven, "Risk Assessment and Risk Management: Review of Recent Advances on Their Foundation," *European Journal of Operational Research* 253, no. 1 (August 16, 2016): 1-13, <https://doi.org/10.1016/j.ejor.2015.12.023>.

⁸ Christopher B. Field, *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK: Cambridge University Press, 2012).

⁹ Brian C. O'Neill et al., "IPCC Reasons for Concern Regarding Climate Change Risks," *Nature Climate Change* 7, no. 1 (January 4, 2017): 28-37, <https://doi.org/10.1038/nclimate3179>.

¹⁰ Hans Rosling et al., *Factfulness: Ten Reasons We're Wrong about the World - and Why Things Are Better than You Think* (New York, NY: Flatiron Books, 2018).

¹¹ David Ropeik, *How Risky Is It Really?: Why Our Fears Don't Always Match the Facts* (New York, NY: McGraw-Hill, 2010).

¹² Paul Slovic, "Perception of Risk," *Science* 236, no. 4799 (April 17, 1987): 280-285, <https://doi.org/10.1126/science.3563507>.

¹³ Carl Cranor, "A Plea for a Rich Conception of Risks," in *The Ethics of Technological Risk*, ed. L. Asveld and S. Roeser (London, UK: Routledge, 2008).

¹⁴ Nicolas Espinoza, "Incommensurability: The Failure to Compare Risks," in *The Ethics of Technological Risk*, ed. L. Asveld and S. Roeser (London, UK: Routledge, 2008).

¹⁵ Daniel J. Rozell, *Dangerous Science* (London, UK: Ubiquity Press, 2020).

¹⁶ Mary Douglas and Aaron Wildavsky, *Risk and Culture an Essay on the Selection of Technological and Environmental Dangers* (Berkeley, CA: Univ. of California Press, 1983).

¹⁷ Elizabeth Fisher and Judith S. Jones, *Implementing the Precautionary Principle: Perspectives and Prospects* (Cheltenham, UK: Edward Elgar Publishing Limited, 2006).

¹⁸ G. K. Chesterton, "The Fulfillment of Wishes," Chesterton Digital Library, November 22, 1913, <https://library.chesterton.org/the-fulfillment-of-wishes-40578/>.

¹⁹ Terje Aven, "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices," *Reliability Engineering & Amp; System Safety* 167 (November 2017): 42-48, <https://doi.org/10.1016/j.res.2017.05.006>.

²⁰ Frank H. Knight, *Risk, Uncertainty and Profit* (Boston, MA: Houghton, 1921).

²¹ Ortwin Renn et al., "Coping with Complexity, Uncertainty and Ambiguity in Risk Governance: A Synthesis," *AMBIO* 40, no. 2 (February 3, 2011): 231-246, <https://doi.org/10.1007/s13280-010-0134-0>.

- ²² Benoit B. Mandelbrot and Richard L. Hudson, *The (Mis)Behaviour of Markets: A Fractal View of Risk, Ruin, and Reward* (London, UK: Profile Books, 2010).
- ²³ Ibid.
- ²⁴ Andy Stirling, "Risk, Uncertainty and Precaution: Some Instrumental Implications from the Social Sciences," *Negotiating Environmental Change*, 2003, <https://doi.org/10.4337/9781843765653.00008>.
- ²⁵ Ortwin Renn and Andreas Klinke, "Systemic Risks: A New Challenge for Risk Management," *EMBO Reports* 5, no. S1 (November 2004), <https://doi.org/10.1038/sj.embo.7400227>.
- ²⁶ Emmy Wassenius and Beatrice I. Crona, "Adapting Risk Assessments for a Complex Future," *One Earth* 5, no. 1 (January 21, 2022): pp. 35-43, <https://doi.org/10.1016/j.oneear.2021.12.004>.
- ²⁷ Ibid.
- ²⁸ R. Flage and T. Aven, "Emerging Risk – Conceptual Definition and a Relation to Black Swan Type of Events," *Reliability Engineering & System Safety* 144 (December 2015): 61-67, <https://doi.org/10.1016/j.res.2015.07.008>.
- ²⁹ Han Fei Tzu and W. K. Liao, *The Complete Works of Han Fei Tzu: A Classic of Chinese Political Science* (London, UK: Arthur Probsthain, 1959).
- ³⁰ Ortwin Renn and Andreas Klinke, "Systemic Risks."
- ³¹ David King et al., "Climate Change: A Risk Assessment" (Cambridge, UK, 2015).
- ³² Aekapol Chongvilaivan, "Thailand's 2011 Flooding: Its Impact on Direct Exports, and Disruption of Global Supply Chains," *ARTNeT Working Paper Series* 113 (2012).
- ³³ Ibid.
- ³⁴ Andy Stirling, "Keep It Complex," *Nature* 468, no. 7327 (December 23, 2010): 1029-1031, <https://doi.org/10.1038/4681029a>.
- ³⁵ Terje Aven, "Risk Assessment and Risk Management."
- ³⁶ Ortwin Renn et al., "Coping with Complexity."
- ³⁷ Ibid.
- ³⁸ Daniel J. Rozell, *Dangerous Science*.
- ³⁹ Albert Wohlstetter, "No Highway to High Purpose," Rand Corporation, 1960, <https://doi.org/10.7249/p2084>.
- ⁴⁰ Ortwin Renn and Andreas Klinke, "Systemic Risks."
- ⁴¹ Ibid.
- ⁴² Alex Epstein, *The Moral Case for Fossil Fuels* (New York, NY: Portfolio/Penguin, 2015).
- ⁴³ "Don't Look Up," Don't Look Up (Netflix, December 24, 2021), <https://www.netflix.com/title/81252357>.
- ⁴⁴ Nassim Nicholas Taleb et al., "The Precautionary Principle (with Application to the Genetic Modification of Organisms)," October 2014, <https://doi.org/https://doi.org/10.48550/arxiv.1410.5787>.
- ⁴⁵ Andy Stirling, "Keep It Complex."
- ⁴⁶ John Horgan, "The New Challenges," *Scientific American* 267, no. 6 (December 1992): 16-23.
- ⁴⁷ J Sillmann et al., "ISC-UNDRR-RISK KAN Briefing Note on Systemic Risk" (Paris, FR: International Science Council, 2022).
- ⁴⁸ Anthony Oliver-Smith et al., "Forensic Investigations of Disasters (FORIN): a Conceptual Framework and Guide to Research," *Integrated Research on Disaster Risk*, 2016.
- ⁴⁹ Arabella Fraser et al., "Developing Frameworks to Understand Disaster Causation: From Forensic Disaster Investigation to Risk Root Cause Analysis," *Journal of Extreme Events* 03, no. 02 (2016): 1650008, <https://doi.org/10.1142/s2345737616500081>.
- ⁵⁰ W. Neil Adger et al., "Advances in Risk Assessment for Climate Change Adaptation Policy," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 376, no. 2121 (2018): 20180106, <https://doi.org/10.1098/rsta.2018.0106>.
- ⁵¹ Marshall Shepherd @DrShepherd2013, "I have long argued climate messaging needs to be about here and now, kitchen table issues...not 8 decades from now or way in the Arctic," Twitter, February 12, 2022, <https://mobile.twitter.com/DrShepherd2013/status/1492506606583656450>.
- ⁵² "Warsaw International Mechanism for Loss and Damage Associated with Climate Change Impacts," United Nations Framework Convention on Climate Change, accessed May 26, 2022, <https://unfccc.int/topics/adaptation-and-resilience/workstreams/loss-and-damage/warsaw-international-mechanism>.
- ⁵³ "Sendai Framework for Disaster Risk Reduction 2015-2030," World Health Organization, 2015, <https://www.who.int/publications/m/item/sendai-framework-for-disaster-risk-reduction-2015-2030>.
- ⁵⁴ C P Weaver et al., "Reframing Climate Change Assessments around Risk: Recommendations for the US National Climate Assessment," *Environmental Research Letters* 12, no. 8 (2017): 080201, <https://doi.org/10.1088/1748-9326/aa7494>.

- ⁵⁵ Swenja Suminski et al., “Assessing Climate Risks across Different Business Sectors and Industries: An Investigation of Methodological Challenges at National Scale for the UK,” *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 376, no. 2121 (April 30, 2018): 20170307, <https://doi.org/10.1098/rsta.2017.0307>.
- ⁵⁶ Andy J. Challinor et al., “Transmission of Climate Risks across Sectors and Borders,” *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 376, no. 2121 (April 30, 2018): 20170301, <https://doi.org/10.1098/rsta.2017.0301>.
- ⁵⁷ Ibid.
- ⁵⁸ C P Weaver et al., “Reframing Climate Change Assessments.”
- ⁵⁹ Thomas Rodham Wells, “Debating Climate Change: The Need for Economic Reasoning,” The Philosopher’s Beard, September 10, 2012, <http://www.philosophersbeard.org/2012/09/debating-climate-change-need-for.html>.
- ⁶⁰ “The Origins of the IPCC: How the World Woke up to Climate Change,” International Science Council, March 10, 2018, <https://council.science/current/blog/the-origins-of-the-ipcc-how-the-world-woke-up-to-climate-change/>.
- ⁶¹ Bernie Lewin, *Searching for the Catastrophe Signal: The Origins of the Intergovernmental Panel on Climate Change* (Melbourne, AU: The Global Warming Policy Foundation, 2017).
- ⁶² Adam Lucas, “Risking the Earth Part 1: Reassessing Dangerous Anthropogenic Interference and Climate Risk in IPCC Processes,” *Climate Risk Management* 31 (2021): 100257, <https://doi.org/10.1016/j.crm.2020.100257>.
- ⁶³ Ibid.
- ⁶⁴ Adam Lucas, “Risking the Earth Part 2: Power Politics and Structural Reform of the IPCC and UNFCCC,” *Climate Risk Management* 31 (2021): 100260, <https://doi.org/10.1016/j.crm.2020.100260>.
- ⁶⁵ Mike Hulme and Martin Mahony, “Climate Change: What Do We Know about the IPCC?,” *Progress in Physical Geography: Earth and Environment* 34, no. 5 (June 18, 2010): 705-718, <https://doi.org/10.1177/0309133310373719>.
- ⁶⁶ Adam Lucas, “Risking the Earth Part 2.”
- ⁶⁷ Thomas Rodham Wells, “Debating Climate Change.”
- ⁶⁸ Alex Epstein, *The Moral Case for Fossil Fuels*.
- ⁶⁹ Rafaela Hillerbrand and Michael Ghil, “Anthropogenic Climate Change: Scientific Uncertainties and Moral Dilemmas,” *Physica D: Nonlinear Phenomena* 237, no. 14-17 (August 15, 2008): 2132-2138, <https://doi.org/10.1016/j.physd.2008.02.015>.
- ⁷⁰ Terje Aven, “Climate Change Risk – What Is It and How Should It Be Expressed?,” *Journal of Risk Research* 23, no. 11 (November 9, 2019): 1387-1404, <https://doi.org/10.1080/13669877.2019.1687578>.
- ⁷¹ John Dewey, *Logic: The Theory of Inquiry* (New York, NY: Holt, Reinhart and Winston, 1938).
- ⁷² Terje Aven, “Climate Change Risk.”
- ⁷³ Terje Aven, “Risk Assessment and Risk Management.”
- ⁷⁴ Hui-Min LI et al., “Understanding Systemic Risk Induced by Climate Change,” *Advances in Climate Change Research*, June 2021, <https://doi.org/10.1016/j.accre.2021.05.006>.
- ⁷⁵ Ibid.
- ⁷⁶ Michael Obersteiner et al., “Managing Climate Risk” (Laxenburg, AT: International Institute for Applied Systems Analysis, 2001).
- ⁷⁷ Mark Carney, “Breaking the Tragedy of the Horizon – Climate Change and Financial Stability,” Bank for International Settlements, September 29, 2015, <https://www.bis.org/review/r151009a.pdf>.
- ⁷⁸ Christa Clapp et al., “Shades of Climate Risk. Categorizing Climate Risk for Investors,” CICERO Research Archive (CICERO Center for International Climate and Environmental Research - Oslo, 2017), <https://pub.cicero.oslo.no/cicero-xmlui/handle/11250/2430660>.
- ⁷⁹ Matthew Scott et al., “The Bank’s Response to Climate Change,” Bank of England, June 16, 2017, <https://www.bankofengland.co.uk/quarterly-bulletin/2017/q2/the-banks-response-to-climate-change>.
- ⁸⁰ Keith Porter et al., *Overview of the Arkstorm Scenario* (Reston, VA: Dept. of the Interior. U.S. Geological Survey, 2011).
- ⁸¹ “The Great California Shakeout,” Great ShakeOut Earthquake Drills, 2008, <https://www.shakeout.org/california/scenario/>.
- ⁸² Keith Porter et al., *Overview of the Arkstorm Scenario*.
- ⁸³ David King et al., “Climate Change: A Risk Assessment.”
- ⁸⁴ Thomas Rodham Wells, “Debating Climate Change.”
- ⁸⁵ Margaret J. Wheatley, *Turning to One Another: Simple Conversations to Restore Hope to the Future* (San Francisco, CA: Berrett-Koehler, 2002).

⁸⁶ Dickon Pinner et al., “Addressing Climate Change in a Post-Pandemic World,” McKinsey & Company (McKinsey & Company, April 7, 2020), <https://www.mckinsey.com/business-functions/sustainability/our-insights/addressing-climate-change-in-a-post-pandemic-world>.

⁸⁷ Ibid.

⁸⁸ Ibid.

⁸⁹ Geoffrey Saville, “The Wicked Problems of Pandemics and Climate Change,” Willis Towers Watson, June 3, 2020, <https://www.wtwco.com/en-US/Insights/2020/05/the-wicked-problems-of-pandemics-and-climate-change>.

1 SUMMARY EVALUATION OF NCA5

This Chapter presents a summary evaluation relative the charge we received from the OSTP: whether NCA5: (1) complied with the USGCRP's statutory obligation, (2) adheres to the core tenets of Gold Standard Science, and (3) can suitably inform federal climate and energy policy. The points made in this summary analysis refers to specific sections of this report as well as to the CWG25 Report.

1.1 Compliance with USGCRP's statutory obligation

As cited in Section 1.2 of this Report, the NCA Reports have a statutory obligation to prepare an assessment which:

- (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings;
- (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

With respect to these obligations, we have identified the following major shortcomings in NCA5:

- Failure to assess adequately the core of climate science and the hazard elements of climate impacts. Instead, the NCA5 focuses on evaluation of societal vulnerabilities, "Climate Action," and policy recommendations with a social justice emphasis (Section 1.2).
- Overconfidence in conclusions and inadequate assessment of uncertainty (Sections 3.1, 5)
- Failure to adequately discriminate between natural and human-induced causes of trends and impacts (Chapter x NEW)
- Failure to adequately analyze current trends owing to reliance on short time periods for trend analysis (Chapter 6)
- Failure to critically evaluate emission scenarios and climate model simulations in making projections for the next 25 to 100 years (Chapter 6; Chapter xx in CWG25).

1.2 Adherence to the tenets of Gold Standard Science

With respect to the tenets of Gold Standard science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

We have identified the following major shortcomings in the NCA5:

- Lack of reproducibility. In the few examples that we examined closely, we identified one instance where we could not reproduce the findings of the NCA5 that should require only rudimentary data analysis (Section 4.1)
- Lack of transparency. In many instances, the Traceable Account fails to provide the appropriate justification for the Key Finding. Metadata was not readily accessible.
- Inadequate communicative of error and uncertainty. The Traceable Account for each Key Message provides a section on Major Uncertainties and Research Gaps; most of the accounts that we examined were superficial and uninformative. (Chapter 5)
- Not skeptical of findings and assumptions. The main text of the Chapters is, with few exceptions, not skeptical of its findings and assumptions. (Chapters 3, 5)
- Some hypotheses and Key Messages are not falsifiable. Many of the Key Messages are not scientific statements nor are they falsifiable. Here is one of many such examples: “Key Message 13.4 Equitable Distribution of Transportation Trade-offs and Benefits Requires Community Involvement.”
- Failure to acknowledge benefits of warming and additional atmospheric CO₂ (REFER TO CWG25)
- Inadequacy of the peer review process. The National Academies of Science, Engineering and Medicine (NASEM) undertook a detailed review of the draft NCA5 (NASEM 2023). While they raised some of the same concerns that we have articulated herein, their review is superficial overall and appears to be written by authors who share many of the biases of the NCA5 team. There is an inordinate focus on social and policy issues (e.g., every chapter is assessed under the heading “Comments on Equity and Justice”), rather than on the underlying science. In our assessment NASEM failed to apply the serious rigor one would expect. (Section 1.4, NEW CHAPTER)

1.3 Suitability for informing federal climate and energy policy

When scientific reports are being assembled that will be highly influential on policymaking, there are other desiderata (beyond the issues mentioned in sections 1 and 2 above), including statements about the strength of knowledge. The IPCC’s approach to assessing strength of knowledge is based on judgment of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include those provided by risk scientist Terje Aven (Aven 2017). The following elements are enumerated, with specific examples where NCA5 falls short in its knowledge characterization:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge—concern about NCA5 focus on implausible extreme emissions and sea level rise scenarios
- The degree to which data/information exists and are reliable and relevant—NCA5 assessment of data quality and selection of short time periods for analysis falls does not support conclusions with high confidence.
- The degree to which there is disagreement among experts (including those from different environments or academic fields)—while the NCA5 is an interdisciplinary effort, skeptical

Commented [A1]: Terje Aven, “Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices,” Reliability Engineering & System Safety 167 (November 2017): 42–48

[HYPERLINK
“<https://www.sciencedirect.com/science/article/pii/S0951832016306950>”]

voices (such as the authors of this Report) were not included in the assessment or NASEM review process.

- The degree to which the phenomena involved are understood and accurate models exist—the NCA5 did not express appropriate levels of skepticism about climate models for purposes of attribution of the causes of warming and extreme events or for future projections.
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns and—the most obvious NCA5 shortcoming in this regard is relative neglect of natural climate variability

NCA5 is further problematic as a document to inform policy making because of the hyperbolic language employed to promote alarm and to advocate for specific policies. In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to “save the planet.” The NASEM Review of the NCA5 underscores the endemic nature of this problem – their review appears to be written by authors who share many of the biases of the NCA5 team with an inordinate focus in the review on social and policy issues (e.g., every chapter is assessed under the heading “Comments on Equity and Justice”), rather than on the underlying science.

So it is not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public’s right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem in a 1980 [[HYPERLINK "https://science.sciencemag.org/content/208/4448/1093"](https://science.sciencemag.org/content/208/4448/1093)] that resonates eerily four decades later:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

1.4 Recommendations for NCA6

In view of the substantial problems with NCA5 in failing to comply with the USGCRP mandate and the tenets of Gold Standard Science, along with the endemic bias in the climate community towards alarmism and policy advocacy on the issue of climate change, there is not a clear path forward for the NCA6 at this time.

There are three fundamental issues to be addressed to support the USGCRP and federal policy making:

- A review of climate science (we suggest that the CWG25 Report meets this object)
- An assessment of weather- and climate-related hazards with an overview of approaches to reduce vulnerability through adaptation

- An evaluation of previous funding by USGCRP and recommendations for the future.

Review of the Fifth National Climate Assessment

Exec Summary

Commented [SK1]: Text needs to be worked on AFTER report sections are nailed down

The fifth National Climate Assessment (NCA5) by the U.S. Global Change Research Program (USGCRP) fails to meet the statutory requirements of the Global Change Research Act of 1990 (GCRA)¹ and violates Executive Order 14303, “Restoring Gold Standard Science” (EO14303).²

Under the GCRA’s terms, the USGCRP must issue periodic assessments to update policymakers on a variety of global changes. To fulfill its statutory mission to “describe and understand” the Earth’s systems and human impacts on them, such a report should be comprehensive, objective. However, USGCRP assessments have ~~become climate-focused documents that serve to increasingly served to justify predetermined policy and societal actions.~~

Commented [RS2]: My changes here are meant to distinguish our approach from that of previous NCAs: I think hundreds of previous authors would object to the inference they were not comprehensive, or lacked scientific integrity.

Politicization of climate science is endemic owing to the international imperative of NetZero. Even in this context, the NCA5 is far more biased than the IPCC AR6 WG1 Report. Evidence of bias in the NCA5 includes:

Biased authors. The NCA5’s list of 500 authors was lauded by the NASEM review (footnote) for its racial diversity. However, this list did not include any university or government scientists whose research and perspective challenged the prevailing narrative. Instead, they included N authors employed by NGOs, most of which are political advocacy organizations. They did not include any authors from industry. ~~CHECK. WE DON’T WANT TO GO THERE~~

Biased attribution. The NCA5 implicitly assumes that all warming is caused by anthropogenic emissions. Further, they attribute many impact drivers and extreme weather events to anthropogenic emissions, well beyond the IPCC AR6 WG1 assessment

Cherry picking of US weather and climate data. In most analyses, the NCA5 neglected to include data prior to 1950 (and in some cases prior to 1970), eliminating from consideration the 1930s – a decade with the worst heat waves and droughts and even the worst US landfalling hurricane.

¹ [HYPERLINK "<https://www.globalchange.gov/about-us/legal-mandate>"]

² [HYPERLINK "<https://www.federalregister.gov/documents/2025/05/29/2025-09802/restoring-gold-standard-science>"]

Lack of reproducibility. JOHN CHRISTY

Assumption that warming is dangerous. The NCA5 neglects benefits from more CO₂ in the atmosphere and from warming.

Implausible extreme emissions scenarios. It is now well known that the extreme emissions scenarios are implausible – UN climate negotiators (COP) have dropped the extreme emissions scenarios from their analyses and projections since 2021. Nevertheless, a word search of the NCA5 shows that a majority of the mentions were of the extreme emissions scenario

Uncritical acceptance of climate model outputs. The NCA5 uncritically accepts climate model outputs for regional climate impact assessments and 21st century projections. This uncritical acceptance is not justified in the Report, and is at odds with IPCC AR6 WG1 Report (Chapter 10)

Overconfidence of conclusions. The terminology NCA5 uses for confidence levels is inflated, leading to overconfidence in the conclusions. ~~NCA5 conclusions with medium confidence are justified by “Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.) competing schools of thought. NCA conclusions with high confidence are justified by “Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus (DESCRIBED AT LENGTH ELSEWHERE~~

Failure to adequately assess uncertainties. The NCA5 briefly mentions uncertainties for each major conclusion in a Traceability Account at the end of each chapter. These uncertainties are ~~not included in the main text and~~ do not appear to influence the conclusions or the confidence levels. The main text neglects obvious representations of uncertainty such as the statistical significance of trends

Emphasis on a single solution. The document advocates extensively for ~~for a single solution—~~ replacement of fossil fuels with wind and solar power ~~CHECK~~

The magnitude of the bias and lack of objectivity in the NCA5 Report is evidenced by comparing it with our DOE document. This document was authored by five scientists whose research and perspectives challenge the prevailing narrative – a category of author that was not included by the NCA5. The DOE included topics and data that were not included in the NCA5, and drew substantially different conclusions from the NCA5, particularly in context of a more comprehensive uncertainty analysis. ~~ETC~~

Introduction

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix XX) that we assess the suitability of the Fifth National Climate Assessment for informing climate and energy policies.

To carry out our work To conduct this assessment, we reviewed NCA5 itself, NASEM review of the Third Order Draft and the USGCRP responses to the review. We have also drawn upon our experience in reading, writing, and leading advisory reports.

We find that NCA5 should not be relied on for policymaking as it is an incomplete and misleadingly picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 is most obviously incomplete because there have been significant developments in climate science since its literature cutoff date of 2022. We have reviewed those developments in a separate report to Energy Secretary Wright. NO PARA BREAK

As importantly further, NCA5 misleads in its portrayal of climate science by omitting key elements of data or understanding even as of 2023. In short, it is completely factual, but factually incomplete. I DON'T LIKE THIS STATEMENT HERE—IT IMPLIES THAT THE NCA5 IS COMPLETELY FACTUAL—The overall effect of those omissions is an excessively dire picture of climate risk.

Our report begins with background on the National Climate Assessments. We then discuss the standards by which we have assessed NCA5, followed by specific deficiencies that we have we've identified. The final section offers some recommendations on the substance and process for the next National Climate Assessment, NCA6, due ???

About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change, but also sought to identify potential adaptation measures and identify the highest priorities for future research.

- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences.
- NCA4 (2017/2018) was an expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science. NCA4 introduced a traceability analysis for each key finding, including a cursory description of uncertainties.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis. NCA5’s self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (see the Box nearby for an example). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

START BOX

NCA4’s Figure ES.5: A Tale of Deception and Review Failure

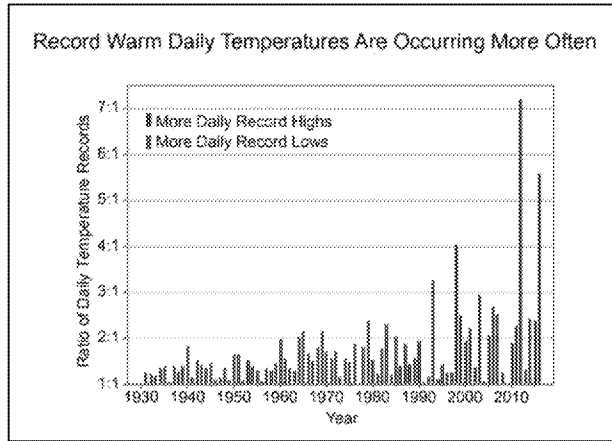
A disappointing example of NCA4’s misrepresentation of climate science involves U.S. temperature extremes. Here is a summary of the issue; details can be found in [Koonin \(2024\)](#).

Commented [SK3]: Cite Unsettled, 2nd edition

NCA4’s Part I (Climate Science Special Report, CCSR) says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:



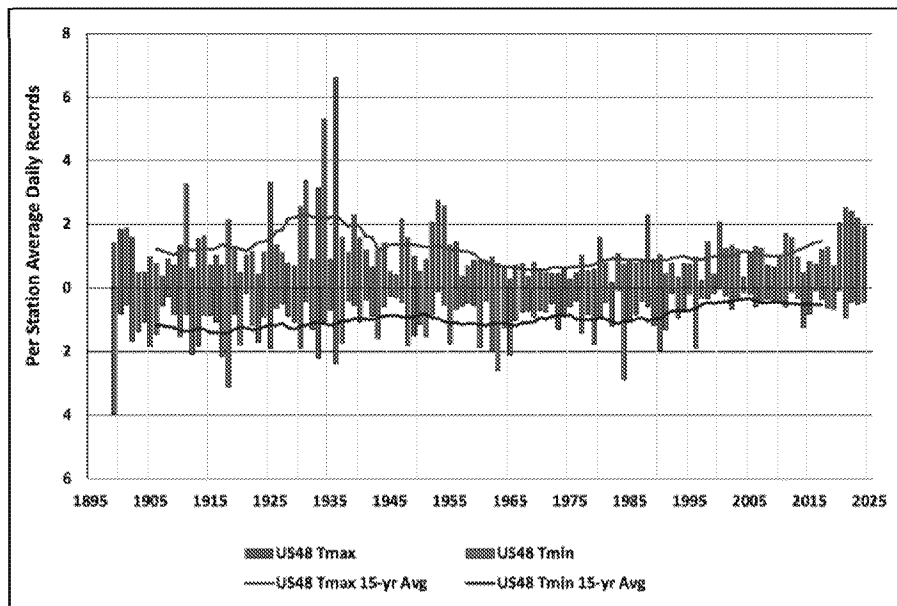
CSSR Figure ES.5 The ratio of the number of daily record high temperatures to daily record low temperatures for many stations across the 48 contiguous states is shown for each year from 1930 to 2017. The lighter bars show a year in which there were more record highs than lows, while the darker bars show years in which there were more record lows than highs. The height of the bar indicates the ratio of record highs to record lows for each year. For example, a ratio of 2:1 for a dark bar means that the stations had twice as many record daily lows as record daily highs for that year. (CSSR, 2017)

Commented [SK4]: Cite CSSR

Three idiosyncratic choices combine to generate the figure's seemingly alarming rise in recent decades. First, because the record extremes tallied are defined conventionally (i.e., each more extreme than any preceding value in the history), the numbers of record highs and record lows are both expected to decline through the years (it becomes increasingly unlikely that a record will be exceeded). Second, the graph displays not the numbers of record highs and lows, but rather their ratio. And finally, the history begins only in 1930 when, in fact, data exist beginning in the late 19th Century. The upshot of these choices is that the resultant figure is guaranteed to show a long period of quiescence around followed by dramatic variations, creating the impression of large changes in recent decades, even if they aren't present.

Figure 6.3.3 of our report (reproduced below) shows the results of a proper analysis – defining each record as the singular extreme in the history, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. On the cold side, the Valentine's Day Arctic outbreak in Feb 1899 stands as the most extensive cold extreme experienced by CONUS, with 1917 in 2nd place. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the extreme T_{max} records were achieved in the last quarter, in accordance with statistical expectations. As a result, the ratio shown in the CSSR explodes in recent decades. And the overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the title of the CSSR figure, "Record Warm Daily Temperatures Are Occurring More Often".

Commented [SK5]: What do we call it?



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature.]

Commented [SK6]: Cite our report

The National Academies' expert review panel [[HYPERLINK "https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report"](https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report)] the discussion of temperature extremes in a [[HYPERLINK "https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf"](https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf)] of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) [[HYPERLINK "https://science.2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf"](https://science.2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf)] to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The “new figure” referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies’ panel. It seems unlikely that the Academies’ panel ever saw that figure because they surely would have commented if they had and it wouldn’t have survived to publication. And the figure’s problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

While the following statement has far less headline potential than that from the CSSR’s page 19 quoted at the beginning of this box, it has advantage of being correct:

There have been some changes in temperature extremes across the contiguous United States. The annual number of high temperature records set shows no significant trend over the past century ~~nor over the past 40 years~~, but the annual number of record cold nights has declined by a factor of 4 since 1895, somewhat more rapidly in the past 30 years.

Commented [SK7]: Check this statement

END BOX

Standards for Assessing NCA5

Good climate and energy policies will balance the risks and benefits of a changing climate against the world’s growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics—the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects ~~are the only people who can~~ bring the facts to the discussion and so have a unique responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.

Because climate is at the core of human existence, it can engender passion and emotion. Indeed, some younger climate scientists have gone into the field to “save the planet.” So it isn’t surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. ~~When that happens, it~~ This lack of objectivity usurps the public’s right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem in a 1980 [HYPERLINK "<https://science.sciencemag.org/content/208/4448/1093>"] that resonates eerily four decades later:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

Good scientific input to policymaking starts with good science. President Trump's executive order of May 23, 2025, "[HYPERLINK "https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/"]" enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some have found them [HYPERLINK "https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science"].

But advice on climate risk has other desiderata, including statements about the strength of climate knowledge. The IPCC's approach is based on judgment of the available evidence and agreement among experts. More {sophisticated knowledge characterizations }for risk management include: REFERENCE AVEN

- The degree to which the assumptions made are reasonable/realistic based on background knowledge—concern about the focus on implausible emissions scenarios RCP8.5/SSP 5–8.5
- The degree to which data/information exists and are reliable and relevant—the historical and paleo database is inadequate for a complete characterization of natural climate variability on multi-decadal to millennial time scales
- The degree to which there is disagreement among experts (including those from different environments or academic fields)—attempts to suppress disagreement and alternative perspectives among experts
- The degree to which the phenomena involved are understood and accurate models exist—concerns about the fidelity and utility of climate models
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns and—neglect of the unknown knowns associated with natural climate variability

Deficiencies in NCA5

We summarize here some salient deficiencies we've identified in NCA5. Some of them are {endemic} while others are specific to key points that NCA5 makes; some deficiencies have developed as the result of new data or analyses since NCA5's preparation in 2023.

In identifying these deficiencies, we have examined NCA5 itself, the NASEM review of it's the Third Order Draft and USGCRP response to that review, as well as prior NCA Reports. We have also drawn upon our

Commented [SK8]: Terje Aven, "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices," Reliability Engineering & System Safety 167 (November 2017): 42–48

[HYPERLINK "https://www.sciencedirect.com/science/article/pii/S0951832016306950"]

Commented [SK9]: My list includes

- models are infallible, with no uncertainties
- weather is climate
- all changes are anthropogenic (climate change vs changing climate)
- the past started in 1950 (ignoring the inconveniently warm 1930s)
- extreme events are increasing
- US mitigation can stop the climate from changing
- use of extreme, implausible scenarios (even through AR6 had already declared SSP8.5 and 7 implausible)
- no mention of benefits of climate change or how they net against disbenefits?
- no mention of uncertainties or significance in trends cited
- no setting of scale for big numbers (e.g., dollars of climate damage relative to GDP)

decades of experience in the science and writing advisory reports, as well as the recent assessment of climate science we prepared for the DOE.

We have limited our scope to focused on NCA5's Chapters 1-3 and selected additional sections. In part because this is the core of our expertise. Further, these chapters cover the foundational climate science, so that the validity of the later chapters rest on them. And if these chapters have so many problems, it's that the subsequent ones will as well.

[few-line descriptions of the individual problems go here. We'll have to see how to parse or group and order them]

- Misrepresentation of changes in extreme precipitation
- Misrepresentation of heat extremes
- Misrepresentation of snowfall [
- Pervasive advocacy language and promotional tone
- Overstating what underlying sources show
- Uncritical definition of scientific "advances"
- Sweeping generalizations regarding complex matters
- Hurricanes
- Projections of Sea Level Rise
- RCP 8.5
- Ambiguous use of "climate change"
- Misrepresentation of historical data
- Misrepresentation of the potential of wind and solar
- ...

Summary Assessment of NCA5

Commented [SK10]: Perhaps move this to the Intro section

As such, the NCA Reports, and particularly the NCA5, are in many ways non-compliant with the GCRA mandate:

- Failure to adequately assess climate science (with the exception of NCA4)
- Failure to adequately consider natural climate variability in attribution analyses and projections
- Failure to adequately assess uncertainties.

Further, the confidence levels in the NCA reports are vastly inflated, based on terminology alone. NCA5 conclusions with medium confidence are justified by "Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.) competing schools of thought. NCA conclusions with high confidence are justified by "Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus.

~~we've not identified all, and there is certainly much that's correct and up to standards, but sufficient problems to discount the whole~~

In summary, the NCA reports have arguably been off the mark since the inception of the program. There are many topics that the NCA should have considered but didn't, and the NCA5 in particular has considered topics outside the remit of the USGCRP. The neglect of critical topics and credible uncertainty analyses has led to bias in the reports.

As such, the NCA reports are not an objective source of information to inform U.S. policy.

Review of the Fifth National Climate Assessment

Exec Summary

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Biased attribution. The NCA5 implicitly assumes that all warming is caused by anthropogenic emissions. Further, they attribute many impact drivers and extreme weather events to anthropogenic emissions, well beyond the IPCC AR6 WG1 assessment

Cherry picking of US weather and climate data. In most analyses, the NCA5 neglected to include data prior to 1950 (and in some cases prior to 1970), eliminating from consideration the 1930s – a decade with the worst heat waves and droughts and even the worst US landfalling hurricane.

¹ [HYPERLINK "https://www.globalchange.gov/about-us/legal-mandate"]

² [HYPERLINK "https://www.federalregister.gov/documents/2025/05/29/2025-09802/restoring-gold-standard-science"]

Lack of reproducibility. JOHN CHRISTY

Assumption that warming is dangerous. The NCA5 neglects benefits from more CO₂ in the atmosphere and from warming.

Implausible extreme emissions scenarios. It is now well known that the extreme emissions scenarios are implausible – UN climate negotiators (COP) have dropped the extreme emissions scenarios from their analyses and projections since 2021 (I have a link for this). Nevertheless, a word search of the NCA5 shows that a majority of the mentions were of the extreme emissions scenario

Uncritical acceptance of climate model outputs. The NCA5 uncritically accepts climate model outputs for region climate impact assessments and 21st century projections. This uncritical acceptance is not justified, and is at odds with IPCC AR6 WG1 Report (Chapter 10)

Overconfidence of conclusions. The terminology NCA5 uses for confidence levels is inflated. NCA5 conclusions with medium confidence are justified by “Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.) competing schools of thought. NCA conclusions with high confidence are justified by “Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus (NOTE THIS TEXT IS FROM NCA4, DOUBT IT CHANGED FOR 5

Failure to assess uncertainties. The NCA5 briefly mentions uncertainties for each major conclusion in a traceability account (in the Appendix?). These uncertainties are not included in the main text and do not appear to influence the conclusions. The main text neglects obvious representations of uncertainty such as the statistical significance of trends CHECK I KNOW THENCA4 had a traceability account for the NCA4, assume they also did for NCA5

Focus on a single solution. The document advocates for a single solution – replacement of fossil fuels with wind and solar power CHECK

The magnitude of the bias and lack of objectivity in the NCA5 Report is evidence by comparing it with our DOE document. This document was authored by five scientists whose research and perspectives challenge the prevailing narrative – a category of author that was not included by the NCA5. The DOE included topics and data that were not included in the NCA5, and drew substantially different conclusions from the NCA5 ETC

Introduction

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix XX) that we assess the suitability of the Fifth National Climate Assessment for informing climate and energy policies.

To carry out our work, we reviewed NCA5 itself, NASEM review of the Third Order Draft and the USGCRP responses to the review. We've also drawn upon our experience in reading, writing, and leading advisory reports.

We find NCA5 should not be relied on for policy making as it is an incomplete and misleadingly picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 is most obviously incomplete because there have been significant developments in climate science since its literature cutoff date of 202?. We have reviewed those developments in a separate report to Energy Secretary Wright.

As importantly, NCA5 misleads in its portrayal of climate science by omitting key elements of data or understanding even as of 2023. In short, it is completely factual, but factually incomplete. The overall effect of those omissions is an excessively dire picture of climate risk.

Our report begins with background on the National Climate Assessments. We then discuss the standards by which we have assessed NCA5, followed by specific deficiencies we've identified. The final section offers some recommendations on the substance and process for the next National Climate Assessment, NCA6, due ???

About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change, but also sought to identify potential adaptation measures and identify the highest priorities for future research.
- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences.

- NCA4 (2017/2018) was an expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science. NCA4 introduced a traceability analysis for each key finding, including a cursory description of uncertainties.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis. NCA5’s self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (see the Box nearby for an example). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

START BOX

NCA4’s Figure ES.5: A Tale of Deception and Review Failure

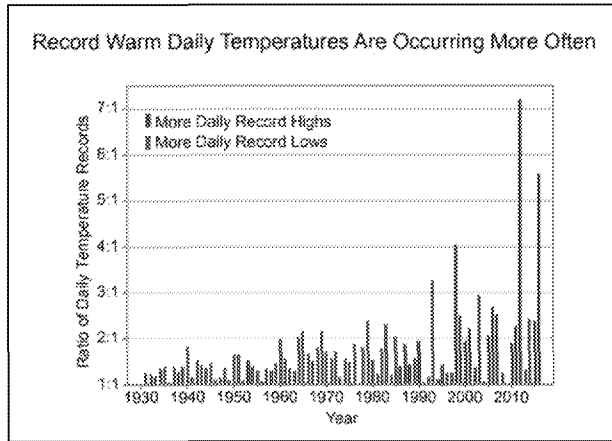
A disappointing example of NCA4’s misrepresentation of climate science involves U.S. temperature extremes. Here is a summary of the issue; details can be found in [Koonin \(2024\)](#).

Commented [SK3]: Cite Unsettled, 2nd edition

NCA4’s Part I (Climate Science Special Report) says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:



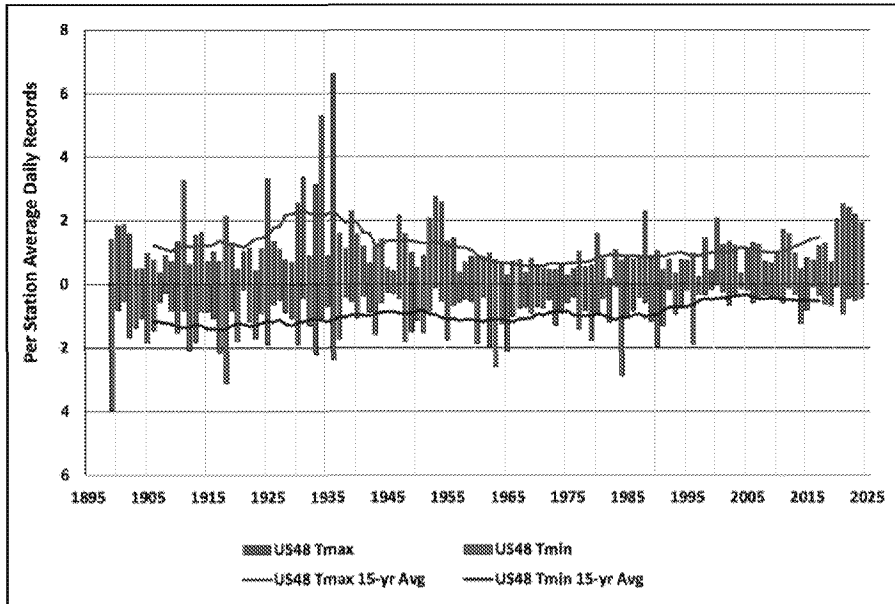
CSSR Figure ES.5 The ratio of the number of daily record high temperatures to daily record low temperatures for many stations across the 48 contiguous states is shown for each year from 1930 to 2017. The lighter bars show a year in which there were more record highs than lows, while the darker bars show years in which there were more record lows than highs. The height of the bar indicates the ratio of record highs to record lows for each year. For example, a ratio of 2:1 for a dark bar means that the stations had twice as many record daily lows as record daily highs for that year. [CSSR, 20XX]

Commented [SK4]: Cite CSSR

Three idiosyncratic choices combine to generate the figure's seemingly alarming rise in recent decades. First, because the record extremes tallied are defined conventionally (i.e., each more extreme than any preceding value in the history), the numbers of record highs and record lows are both expected to decline through the years (it becomes increasingly unlikely that a record will be exceeded). Second, the graph displays not the numbers of record highs and lows, but rather their ratio. And finally, the history begins only in 1930 when, in fact, data exist beginning in the late 19th Century. The upshot of these choices is that the resultant figure is guaranteed to show a long period of quiescence around followed by dramatic variations, creating the impression of large changes in recent decades, even if they aren't present.

Figure 6.3.3 of our report (reproduced below) shows the results of a proper analysis – defining each record as the singular extreme in the history, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climate and, in any event, occurred after the CSSR was published in 2017. On the cold side, the Valentine's Day Arctic outbreak in Feb 1899 stands as the most extensive cold extreme experienced by CONUS, with 1917 in 2nd place. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the extreme Tmax records were achieved in the last quarter, in accordance with statistical expectations. As a result, the ratio shown in the CSSR explodes in recent decades. And the overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the title of the CSSR figure, "Record Warm Daily Temperatures Are Occurring More Often".

Commented [SK5]: What do we call it?



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature.]

Commented [SK6]: Cite our report

The National Academies' expert review panel [[HYPERLINK "https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report"](https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report)] the discussion of temperature extremes in a [[HYPERLINK "https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf"](https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf)] of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) [[HYPERLINK "https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf"](https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf)] to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The “new figure” referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies’ panel. It seems unlikely that the Academies’ panel ever saw that figure because they surely would have commented if they had and it wouldn’t have survived to publication. And the figure’s problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

While the following statement has far less headline potential than that from the CSSR’s page 19 quoted at the beginning of this box, it has advantage of being correct:

There have been some changes in temperature extremes across the contiguous United States. The annual number of high temperature records set shows no significant trend over the past century ~~for over the past 40 years~~, but the annual number of record cold nights has declined by a factor of 4 since 1895, somewhat more rapidly in the past 30 years.

Commented [SK7]: Check this statement

END BOX

Standards for Assessing NCA5

Good climate and energy policies will balance the risks and benefits of a changing climate against the world’s growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics—the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects are the only people who can bring the facts to the discussion and so have a unique responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.

Because climate is at the core of human existence, it can engender passion and emotion. Indeed, some younger climate scientists have gone into the field to “save the planet.” So it isn’t surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. When that happens, it usurps the public’s right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem in a 1980 [[HYPERLINK "https://science.sciencemag.org/content/208/4448/1093"](https://science.sciencemag.org/content/208/4448/1093)] that resonates eerily four decades later:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

Good scientific input to policymaking starts with good science. President Trump's executive order of May 23, 2025, "[[HYPERLINK "https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/"](https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/)]" enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some have found them [[HYPERLINK "https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science"](https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science)]

But advice on climate risk has other desiderata, including statements about the strength of climate knowledge. The IPCC's approach is based on judgment of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge—concern about the focus on implausible emissions scenarios RCP8.5/SSP 5–8.5
- The degree to which data/information exists and are reliable and relevant—the historical and paleo database is inadequate for a complete characterization of natural climate variability on multi-decadal to millennial time scales
- The degree to which there is disagreement among experts (including those from different environments or academic fields)—attempts to suppress disagreement and alternative perspectives among experts
- The degree to which the phenomena involved are understood and accurate models exist—concerns about the fidelity and utility of climate models
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns—neglect of the unknown knowns associated with natural climate variability

Deficiencies in NCA5

We summarize here some salient deficiencies we've identified in NCA5. Some of them are endemic while others are specific to key points NCA5 makes; some deficiencies have developed as the result of new data or analyses since NCA5's preparation in 2023.

In identifying these deficiencies, we have examined NCA5 itself, the NASEM review of its Third Order Draft and USGCRP response to that review, as well as prior NCAs. We have also drawn upon our decades of experience in the science and writing advisory reports, as well as the recent assessment of climate science we prepared for the DOE.

Commented [SK8]: Terje Aven, "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices," Reliability Engineering & System Safety 167 (November 2017): 42–48

[[HYPERLINK "https://www.sciencedirect.com/science/article/pii/S0951832016306950"](https://www.sciencedirect.com/science/article/pii/S0951832016306950)]

Commented [SK9]: My list includes

- models are infallible, with no uncertainties
- weather is climate
- all changes are anthropogenic (climate change vs. changing climate)
- the past started in 1950 (ignoring the inconveniently warm 1930s)
- extreme events are increasing
- US mitigation can stop the climate from changing
- use of extreme, implausible scenarios (even though AR6 had already declared SSP8.5 and 7 implausible)
- no mention of benefits of climate change or how they net against disbenefits?
- no mention of uncertainties or significance in trends cited
- no setting of scale for big numbers (e.g., dollars of climate damage relative to GDP)

We have limited our scope to NCA5's Chapters 1-3 and selected additional sections. In part because this is the core of our expertise. Further, these chapters cover the foundational climate science, so that the validity of the later chapters rest on them. And if these chapters have so many problems, it's that the subsequent ones will as well.

[few-line descriptions of the individual problems go here. We'll have to see how to parse or group and order them.]

- Misrepresentation of changes in extreme precipitation
- Misrepresentation of heat extremes
- Misrepresentation of snowfall [
- Pervasive advocacy language and promotional tone
- Overstating what underlying sources show
- Uncritical definition of scientific "advances"
- Sweeping generalizations regarding complex matters
- Hurricanes
- Projections of Sea Level Rise
- RCP8.5
- Ambiguous use of "climate change"
- Misrepresentation of historical data
- Misrepresentation of the potential of wind and solar
- ...

Summary Assessment of NCA5

Commented [SK10]: Perhaps move this to the Intro section

As such, the NCA Reports, and particularly the NCA5, are in many ways non-compliant with the GCRA mandate:

- Failure to adequately assess climate science (with the exception of NCA4)
- Failure to consider natural climate variability
- Failure to adequately assess uncertainties.

Further, the confidence levels in the NCA reports are vastly inflated, based on terminology alone. NCA5 conclusions with medium confidence are justified by "Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.) competing schools of thought. NCA conclusions with high confidence are justified by "Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus.

we've not identified all, and there is certainly much that's correct and up to standards, but sufficient problems to discount the whole

In summary, the NCA reports have arguably been off the mark since the inception of the program. There are many topics that the NCA should have considered but didn't, and the NCA5 in particular has considered topics outside the remit of the USGCRP. The neglect of critical topics and credible uncertainty analyses has led to bias in the reports.

As such, the NCA reports are not an objective source of information to inform U.S. policy.

Recommendations for NCA6

From Ross

- expand and secure support for basic climate monitoring including the MSU series, Argo floats, radiosondes etc.
- expand discussion of potential benefits of climate change including reduced cold-weather mortality and enhanced CO2 fertilization
- red team review of problems with the global surface thermometer network, including lack of spatial coverage and formal assessment of whether the bias adjustments actually remove known UHI biases
- cull the GCM herd and retire those models that have intractable problems of warming bias
- Invest in substantial efforts to digitize hand-written records of temperature and precip across the US. Basically, hire a team of 100 researchers to see if they can do in 5 years what John does in a month.
- Create a public-facing data dissemination site that provides access to complete records of climate-relevant metrics including extreme weather, in every case showing the entire data set not merely the last 20 years
- Reduce or eliminate regional climate projections on the basis that models are incapable of doing it and the information provided is useless. Focus instead on providing information geared to optimizing adaptation and resilience

Appendix I: Letter requesting this report

To come

Appendix II: NCA5 in its own words

About NCA5 [from its pg xx]

The Global Change Research Act of 1990 mandates that the US Global Change Research Program (USGCRP) deliver a report to Congress and the President not less frequently than every four years that "integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human

social systems, and biological diversity; and analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.'

The Fifth National Climate Assessment (NCAS) fulfills that mandate by delivery of this Assessment and provides the scientific foundation to support informed decision-making across the United States. By design, much of the development of NCAS built upon the approaches and processes used to create the Fourth National Climate Assessment (NCA4),² with a goal of continuously advancing an inclusive, diverse, and sustained process for assessing and communicating scientific knowledge on the impacts, risks, and vulnerabilities associated with a changing global climate (App. 1).

The findings in this report are based on a comprehensive review and assessment of information sources determined to meet the standards and documentation required under the Information Quality Act and the Foundations for Evidence-Based Policymaking Act of 2018 (App. 2), including peer-reviewed literature, other literature, Indigenous Knowledge, other expert and local knowledge, and climate data processed and prepared for authors by NOAA's Technical Support Unit (TSU; see Guide to the Report section below and App. 3).

NCAS was thoroughly reviewed by Federal Government experts, external experts, and the public multiple times throughout the report development process. An expert external review was performed by an ad hoc committee of the National Academies of Sciences, Engineering, and Medicine.³ Additional information on the development of this Assessment can be found in Appendix 1: Assessment Development Process.

NCAS Intended Audience and Scope of Chapters [from its p xxi]

Intended Audience

The products of the US Global Change Research Program are designed to assist the Nation and the world in understanding, assessing, predicting, and responding to human-induced and natural processes of global change. National Climate Assessments synthesize scientific information and evaluate the state of the science on climate change to inform a broad audience of decision-makers across the country. These decision-makers include national, state, local, and Tribal governments, city planners, public health officials, adaptation specialists, nurses, farmers, business owners, community organizers, researchers, water utilities, ecosystem managers, educators, students, the media, and concerned individuals who need to make timely decisions about the climate impacts they are facing. National Climate Assessments make policy-neutral and policy-relevant information accessible and actionable by relying on the expert judgment of the report authors to determine what topics are included in each chapter, to describe what we know and where uncertainties remain, and to clearly communicate the risks, responses, and opportunities associated with climate change.

Overview

The Overview chapter presents the major findings of the report alongside highlights drawn from across NCAS. This chapter provides a synthesis of material from the underlying report chapters.

Physical Science Chapters

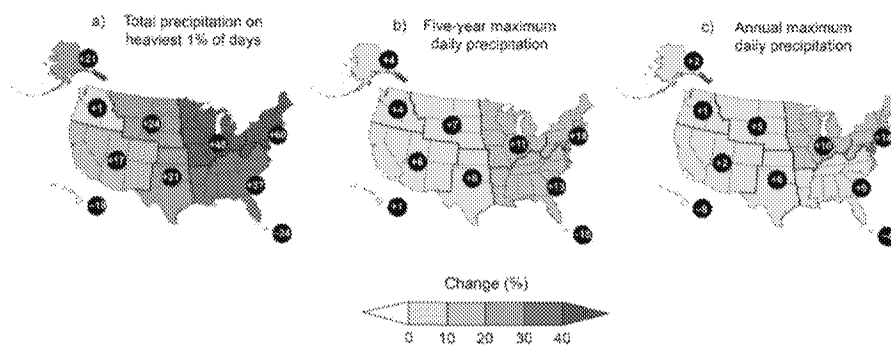
The Climate Trends and Earth Systems Processes chapters (Chs. 2, 3) assess how climate change affects physical Earth systems, with a focus on the United States, including observations and projections of climate change and discussion of how methods to understand changes in Earth systems have advanced since NCA4, which was released in November 2018.

Appendices III: Details of NCA5's deficiencies

Misrepresentation of changes in extreme precipitation [Christy]

Below is Fig. 2.8 from NCA5 indicating heavy, short-duration precipitation events are becoming more frequent and severe, mainly in the Eastern US.

Observed Changes in the Frequency and Severity of Heavy Precipitation Events



Heavy precipitation events are becoming more frequent and intense across much of the country.

FIGURE 2.8. The frequency and intensity of heavy precipitation events have increased across much of the United States, particularly the eastern part of the continental US, with implications for flood risk and infrastructure planning. Maps show observed changes in three measures of extreme precipitation: (a) total precipitation falling on the heaviest 1% of days, (b) daily maximum precipitation in a 5-year period, and (c) the annual heaviest daily precipitation amount over 1958–2021. Numbers in black circles depict percent changes at the regional level. Data were not available for the US Affiliated Pacific Islands and the US Virgin Islands. Figure credits: (a) adapted from Easterling et al. 2017;²⁰⁷ (b, c) NOAA NCEI and OGBSS ND.

The NCA5 concludes from this evidence and citing two papers from model studies,

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.[
HYPERLINK "<https://nca2023.globalchange.gov/chapter/2/>" \ "fn:126"] [HYPERLINK "<https://nca2023.globalchange.gov/chapter/2/>" \ "fn:127"]

A scientific examination of this claim would have considered the following questions among many,

- (1) Why do the analyses begin with 1958 when measurements are available from the late 19th century?
- (2) Given that hydrologic/precipitation events are subject to "Long-Term Persistence" (LTP) where long dry- and wet-spells are common features, is it likely such changes are examples of natural variability for any 64-year period? Are these percentage changes significant?
- (3) Were the climate model simulations subjected to independent evaluation before concluding that they represent not only basic climate variations, but precipitation processes accurately enough to allow someone to conclude that human emissions contributed to the changes?

The Differbaugh et al 2018 citation [126] used a short observational window of 1961-2005 to determine "historical" trends, then analyzed output from the implausible RCP8.5 climate model simulations to claim changes were likely human-caused. [See "BOX: Perils of short data records" Ch6 DoE-CWG 2025].

The Kirchmeier-Young 2020 citation [127] utilized observations for only 1961-2010. The model output again was taken from the implausible RCP8.5 simulations. The model output then had to be multiplied by "scaling factors" to force agreement with the magnitudes of historical observations of extreme events. Furthermore, the focus of the analysis was on the CanESM2 CMP-6 model, one that produced global atmospheric temperature trends that were a factor of 2.5 too positive compared with observations due to excessive sensitivity to GHG forcing (+0.43 vs. +0.17 °C/decade, 1979-2024).

We note the following deficiencies behind NCA's claim (see DoE-CWG Ch4-6 for details on these issues),

- (1) "Historical" results for change-analysis are based on short data periods.
- (2) The emissions scenario employed was the implausible rcp8.5.
- (3) Results are based on overly-sensitive models (ECS up to 5.6 °C).

To understand the character of recent changes against the background of a better-quantified natural variability we constructed continuous daily precipitation datasets for stations within four

regions; (1) Pacific Coast (1893ff) where IPCC AR6 suggested an increase in Atmospheric River events had been observed since 1948, and three regions that NCA5 indicates are experiencing increases in short-duration heavy events; (2) Upper Midwest (1893ff), (3) Humid Southeast (1872ff) and (4) Northeast (1888ff). Surprisingly, NCA5 did not perform significance-testing on the alleged changes.

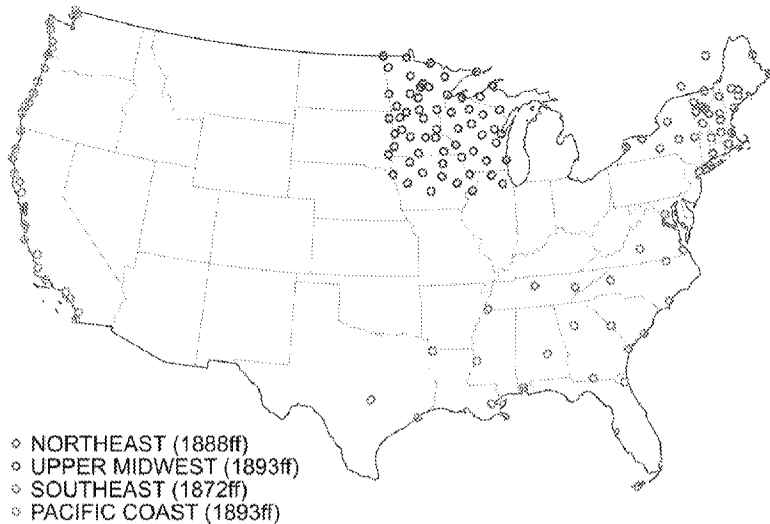


Figure. Location of stations utilized in this study.

Following McKittrick and Christy 2019 (who found no significant changes in the West and Southeast with observations beginning in the late 19th century) we apply the more appropriate statistical analysis which characterizes LTP for precipitation events to determine if these changes are significant. [The critical importance of incorporating LTP is described in Ch6 of the DoE-CWG 2025.]

When using time series > 130 years the results indicate that while some individual stations have significant positive trends in extreme-event totals and occurrences, regional values do not. Thus, attributing a non-significant change in a phenomenon (increased number of heavy precipitation events) to a specific cause (increased concentrations of GHGs as depicted in poor models with implausible inputs) does not support the NCA5 claim that there is “robust evidence” that human emissions are contributing to changes observed. We conclude that the NCA5 methods and conclusions do not meet the very basic standards of scientific analysis.

Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, **4** (2), 3354. [HYPERLINK "<https://doi.org/10.1126/sciadv.aao3354>" \t "_blank"]

Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, **117** (24), 13308–13313. [HYPERLINK "<https://doi.org/10.1073/pnas.1921628117>" \t "_blank"]

Misrepresentation of heat extremes [Christy]

There are mixed (and somewhat convoluted) messages in NCA5 regarding the notion that hot extremes are increasing in the CONUS. In summary-claims, using alarming language, i.e., "record-shattering", attention is drawn to examples in restricted regions in the CONUS or to short, recent time periods. However, the document does occasionally acknowledge the 1930s heatwaves and the overall decline of hot events in the past 100 years. From NCA5 chapter 2,

(Key Message 2.2) Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

The Risk of Temperature Extremes Is Changing

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s.... Several major heatwaves have affected the US since 2018, including a record-shattering event in the Pacific Northwest in 2021. The western US has been particularly affected by extreme heat since the 1980s (Figure 2.7), experiencing a larger increase in days over 95°F, as would be expected given the greater warming in that region relative to the eastern US. By contrast, the number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator (<https://www.globalchange.gov/indicators/heat-waves>) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

Nighttime temperatures are rising faster than daytime temperatures, and the number of nights where the temperature never falls below 70°F is increasing everywhere in the US except the Northern Great Plains (Figure 2.7). The extent of CONUS experiencing hot summernights is growing at a faster rate than the extent experiencing hot summer days.

The NCA6 focused much of the heat discussion on the western CONUS, including the Pacific Northwest heatwave of 2021, as well as rising nighttime temperatures. It only briefly mentions the long-term decline in heat extremes in most of the CONUS. While factually correct in a narrow sense, the full revelation of non-alarming facts is not apparent. We also note the convoluted reasoning in the quote above that hot extremes are apparently due to "greater warming" in the region than experienced elsewhere and that declining hot extremes are "due to summer cooling trends". Since "trends" do not cause changes, one might ask, "What caused the warming *and* cooling trends?"

These heat issues are addressed in Ch6 of the DoE-CWG demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by the chaotic behavior of natural variability than the small extra forcing from the enhanced concentrations of CO₂. The DoE-CWG conclusion is that both in terms of hot days ($\geq 95^{\circ}\text{F}$) and number of days in heatwaves, the current decade is experiencing no more than was experienced 100 years ago. For example, in the 30-year period 1925-1954, representing only 23% of the 1899-2024 data record, the CONUS experienced 33% of the total heat wave days. The most recent 30-years experienced 24%, almost exactly that expected by chance. Thus the claim "multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades," is simply false when beginning in 1899 (Ch6 Fig. 6.3.6 DoE-CWG).

Figure X displays the occurrence of days $\geq 95^{\circ}\text{F}$, showing the increase in the three western regions and declines elsewhere. Additionally, the trends in both heatwave days and hot days are (insignificantly) negative for the CONUS as a whole.

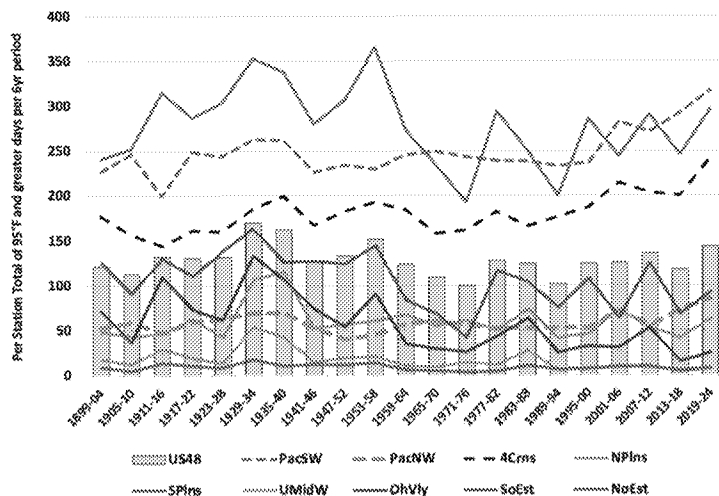


Figure. Number of days $\geq 95^{\circ}\text{F}$ in 6-year periods (1899-2024) for nine CONUS regions (lines, dashed positive trends, solid negative trends) and full CONUS (bars).

The fact (and we agree it is a fact) that summernighttime temperatures have risen rapidly since 1960 nearly everywhere, and especially in the largest cities, is clear. However, this observation is more a consequence of the urban heat island effect (which has greatest impact on stations changing from rural to semi-rural, Ch6 DoE-CWG) and the choice of starting in the 1960's, the coolest decade since the 1910's.

In attributing daims of rising heat extremes to GHG concentrations, the NCA5 concentrated on the localized 2021 event but is silent on the attribution of declining heat extremes in the eastern 2/3 of the CONUS (the statement "due to summer cooling trends" does not suffice) or the major role that the increasing growth of infrastructure around the stations exerts on nighttime temperatures. The scientific method requires one to demonstrate that a daim must represent all of the evidence, not simply a small portion that agrees with the daim. In this instance the NCA5 falls short of rigorously demonstrating that rising GHG concentrations are responsible for the observed changes (or lack thereof) in hot extremes in the CONUS.

Misrepresentation of snowfall [Christy]

The introduction to NCA5 Chapter 4 "Water" is unequivocal and rather ominous.

Climate change is intensifying rainfall and floods, deepening droughts, and shifting weather patterns across the globe, causing profound effects on terrestrial freshwater supplies and quality. Rising sea levels, reduced snowpacks, shrinking rivers, and declining groundwater threaten cities and rural communities and endanger forest, riverine, and other ecosystems across the United States.

The CWG25 report provides evidence that several of these alarming claims are misleading or untrue. Here we examine "Box 4.1 Washington-California 2015 Snow Drought" in which a single season was examined for its record or near-record low snow totals to draw attention to a drying climate in the West. While the introduction shouts about "deepening droughts and shifting weather patterns" in the later text under "Drought Impacts" the NCA5 acknowledges that "Megadroughts are events of extraordinary duration and severity, and many are documented in paleoclimate records." However, this is then followed by more somber statements,

Temperature's contribution to drought makes it clear that warming associated with climate change could increase the frequency, severity, and/or duration of drought and drive aridification, a long-term shift toward a drier climate, which is a concern in already dry parts of the West.

and

In areas of the West where snow is the dominant source of runoff, total seasonal snow water volume is projected to decrease by more than 24% by 2050 under intermediate (RCP4.5) and higher scenarios, with persistent low-snow conditions emerging within the next 60 years.

Thus, on the one hand, major shifts in historical precipitation (and thus snowfall) patterns in the West are well documented in which "megadroughts" - more significant than any dry spell of the past 130 years - are a normal part of the western climate system. On the other hand, the NCA5 informs us that we should be concerned about these patterns as they "shift toward a drier climate".

"Snowfall" is the total of the amount of snow that falls each day accumulated over a season. This is not the more familiar "snowpack on 1 April" which is simply the depth of snow on a single day which represents the snow that has accumulated through the winter but not yet melted. This latter metric is operationally useful for hydrologic projections of spring and summer runoff in the far-western mountains (Cascades in Washington and Oregon and Sierra Nevada in California).

[Snowfall is actually a directly-measured metric as opposed to "water equivalent", the amount of liquid the snow would produce if melted. Before 1960, water equivalent was often not measured at all but simply (and easily) calculated as the new snowfall divided by 10 (examples in Christy 2012).]

Has western snowfall changed as a result of "a long-term shift toward a drier climate"? As noted above, NCA5 cites a modeling study that projects a 24% decline in snowfall by 2050, though total precipitation projections are mixed, being positive for the Cascades and negative for the Sierra Nevada (NCA5 Fig. 4.3).

Christy 2022 examined the snowfall question for the western mountain ranges of the Cascades and Sierra Nevada. Updated information through the 2024-25 season is presented below. Trends since the late 19th century and since 1975 (last 51 years) are insignificant due in part to the high interannual variability, thus an attributable decline has not been detected. The evidence provided here does not suggest a long-term shift toward decreasing snowfall in the mountains of the Pacific West (see also CWG25 6.4).

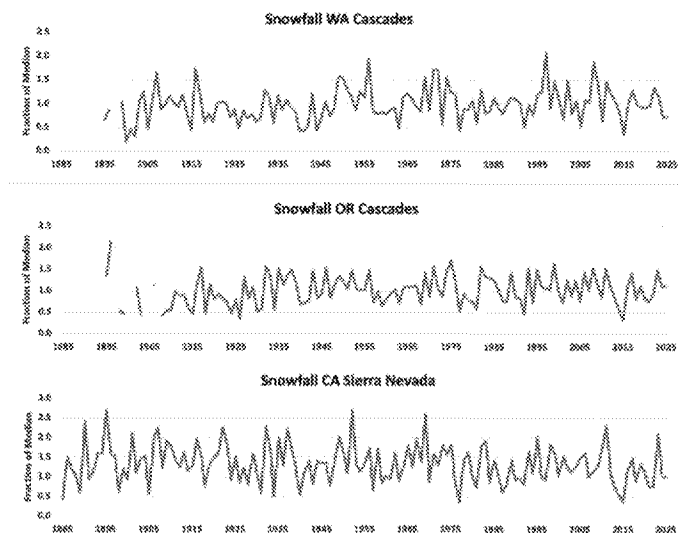


Figure. Nov-Apr snowfall as a fraction of the seasonal median total for the Cascades of Washington (top) and Oregon (center) and the Sierra Nevada of California (bottom).

Christy, JR., 2012: Searching for information in 133 years of California snowfall observations. *J. Hydrometeor.* 13, 895-912. DOI:10.1175/JHC-D-11-040.1.

Christy, JR., 2022: Time series construction of Oregon and Washington snowfall since 1890 and an update of California snowfall through 2020. *J. Hydrometeor.* DOI:10.1175/JHM-D-21-0178.1.

Pervasive advocacy language and promotional tone [McKittrick]

Countless examples.

Ch1 - overview

- Page 1-6 policy advocacy that fails to discuss costs of actions
- "Each additional increment of warming leads to greater risks" but so does each additional increment of measures to reduce GHG emissions
- P. 1-9 uses irrelevant cost measure ("levelized") that ignores quality differences in power sources

- 1-14 includes SSP5-8.5 in list of “plausible futures”
- 1-16 Changes are “unprecedented over thousands of years”: ignores persistent uncertainties in paleo reconstructions and the fact that measurement of pace of change thousands of years ago are very imprecise
- 1-16 refers to trends without reference to the time scale
- 1-17 all statements presented as definitive with no admission of uncertainty or contingency on data quality and estimation methods
- 1-18 uncritically uses Billion Dollar Disaster data set which has been withdrawn
- 1-19 Land Surface Temperature versus median household income within cities has nothing to do with climate. It is more likely that low-income households concentrate where housing is less expensive which tends to be in areas with less parkland and tree cover
- 1-26 projected losses due to flooding ignores current data showing decreasing floods on average [[HYPERLINK "https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding"](https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding)]
- 1-42 makes very non-mainstream assertion about climate economics

Ch 2

Key message 2.1 “Climate Is Changing, and Scientists Understand Why”

- Overly confident language
- 2-4 US warming faster than planet as a whole. But this is trivial since the comparison includes oceans. All land surfaces warm faster than the ocean. So why raise this point?
- PNW heat wave used as an example of validity of extreme event attribution – we address this work in CWG25 report. NCA5 hedges a bit by only saying AGW raised the temperature a couple of degrees. But then:
 - Para 3: CC affecting people, Extreme heat resp for more than 700 deaths per year from 2004 to 2018. But doesn't mention decline in cold weather-related mortality. Then invokes BDD without acknowledging limitations
 - Para 5: Climate change has other consequences... the PNW heat wave caused more than 1400 heat-related deaths (thus insinuating all deaths due to AGW rather than tiny fraction associated with final degree of warming)
- Western wildfires “made more severe by climate change” yet intensity trends don't support this (CWG Fig 6.83) also global data don't support this claim
- “As the Planet Warms, Storms Become More Dangerous”: but the ensuing discussion refers to model forecasts not observations, and does not provide any supporting historical information nor does it acknowledge the observed decline in tornado activity (CWG25 p.67).

Reliance on Billion Dollar Disaster data in multiple places. Even if it hadn't recently been officially withdrawn the authors should have assessed it skeptically and rejected it as unfit for the purpose of measuring climate trends.

p. 3-10 Narrowing range of ECS by 50%.

This section summarizes the issue with way too much confidence. NCA5 says the narrowing has been achieved “through unprecedented quantitative synthesis of evidence from observed

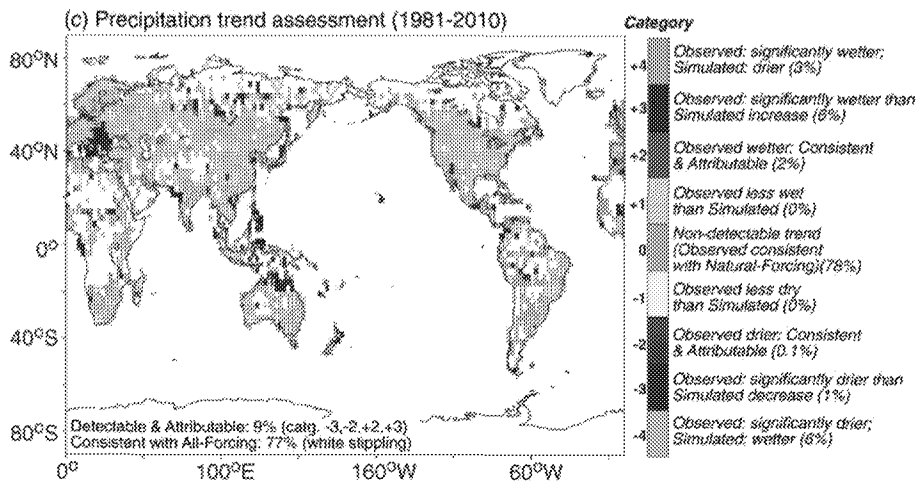
changes over recent decades, the industrial era, and paleoclimate.” It was one study, and it has already received substantial challenge in the literature (CWG 4.3) The NCA5 section provides no discussion of the simultaneous emergence of evidence (especially from the LT and MT) of low ECS.

Overstating what underlying sources show [McKittrick]

P.2-11 increase in precipitation in central and eastern US based on comparison of 2002-2021 average to 1901-1960, which is a weird metric, the change is called a “trend” although that’s not how a trend is measured, and it is “attributable to climate change”. The claims were attributed to

- Knutson and Zeng (2018) “Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends”
Journal of Climate 31(12) [[HYPERLINK](https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml)
"https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml"]

But it did not say these things. It examines linear trends over 1901 – 2010, 1951 – 2010 and 1981 – 2010. It does not compare average rainfall over 2002 - 2021 to average rainfall over 1901 – 1960. With regard to the final period its results are:



Gray indicates no trends detected. Stippling means only that there were no trends in the models either so the models and obs agreed in that respect. Detectable and attributable

trends occur over only 9% of the land surface of the Earth. Over the US there are detectable trends over only a few regions in the SW.

p. 2-18: "There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US"

Attributed to two papers:

Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. [HYPERLINK "<https://doi.org/10.1126/sciadv.aao3354>"]

And

Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308-13313. [HYPERLINK "<https://doi.org/10.1073/pnas.1921628117>"]

Diffenbaugh et al. present ratios of occurrences of extreme events to natural-only simulations from CMIP6 models. They report that for 79% of the U.S. extreme rainfall events are currently greater than frequencies in the models, and the ratio of occurrences will rise under future warming simulations. This is not "robust" evidence of anthropogenic influence, it only shows a discrepancy between models and observations which the authors interpret as evidence of anthropogenic forcing, on the assumption that the discrepancies would disappear if anthropogenic forcing were introduced. However they present no confirmation of that claim.

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using 3 GCMs, found "A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically." However they noted large differences among the three models in their simulated precipitation changes. Also, 2 of the 3 models failed to yield detection for Rx5Day for the NA mean. Finally the authors used TLS, a biased estimation method. Here again this is not "robust" evidence, it is suggestive but other studies have found natural variability predominant.

- 2-19 drought risk. Again a weird trend metric: Colorado River streamflow over 2000-2014 was 19% lower than the 20th century average. Droughts lasting longer and this is not temporary it is a drier "new normal". This is attributed to

Overpeck, J.T. and B. Udall, 2020: Climate change and the aridification of North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (22), 11856-11858. [HYPERLINK "<https://doi.org/10.1073/pnas.2006323117>"]

But this article is only a commentary and does not present any new research. It notes some changes and discusses in qualitative terms that they might be indicators of what's to come in the future.

Only need a few such examples to call into question the carefulness of the research behind the report.

Uncritical definition of scientific "advances" [McKittrick]

p. 3-13ff "New Data and Analysis Methods Have Advanced Climate Science"

This section treats release of new scenarios as a scientific "advance" without addressing the failure of previous scenarios to match reality or the likelihood that the new ones fail in the same regard. It also reports availability of large model ensembles as an advance, without addressing ways in which models are getting worse in some key respects. It also equates the increased use of rapid Extreme Event Attribution as an advance, without assessing whether the technique is valid in the first place.

Emergent constraints likewise discussed in completely uncritical terms:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as "emergent constraints." The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

They fail to discuss any studies showing Emergent Constraints patterned on CMIP5 models failed to work on CMIP6 models, Eg.

- Manuel Schlund, Axel Lauer, Pierre Gentine, Steven C. Sherwood, and Veronika Eyring (2020) Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6? *Earth System Dynamics* 11 1233-1258 [[HYPERLINK "https://doi.org/10.5194/esd-11-1233-2020" \]](https://doi.org/10.5194/esd-11-1233-2020)]

Shows that emergent constraint relationships derived for CMIP5 models fail badly in CMIP6 models:

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for ESMs participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently,

the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet the introduction of emergent constraints is treated as a great “advance” in NCA5.

Sweeping generalizations regarding complex matters [McKittrick]

Example: US precipitation changes.

pp. 2-18-19

“Rainfall is becoming more extreme”

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity. The largest increase in the number of extreme precipitation days (defined as the top 1% of heaviest precipitation events) has occurred over the Northeast (an increase of around 60%) and Midwest (around 45%), along with increases of more than 10% in their annual and 5-year maximum amount (Figure 2.8). These changes have contributed to increases in river and stream flooding in these regions. The increase in frequency and intensity of precipitation extremes is evident across a broad range of event durations (from 1 to 30 days) and return intervals (1 to 20 years), particularly east of the Rocky Mountains.

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US. *Paleoclimate records derived from tree-ring growth* provide evidence that summer moisture has increased over the past century in parts of New England, the central-eastern US, and the northern Mississippi River valley.

Here is a more accurate summary of what the data show based on a sample of 141 very long (>130 years) records of daily precipitation.

There are regionally-heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are

generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution to anthropogenic warming difficult.

Along the Pacific coast very few stations (1 or 2 out of 29) exhibit significant trends on any time scale in any metric and the region-wide trends are insignificant.

In the Southeast region about 5 out of 24 stations exhibit positive trends in average and extreme precipitation metrics and the regional trends are likewise significant, but only on samples beginning in 1950. When the sample starts in 1873 or 1980 the trends weaken and become mostly insignificant.

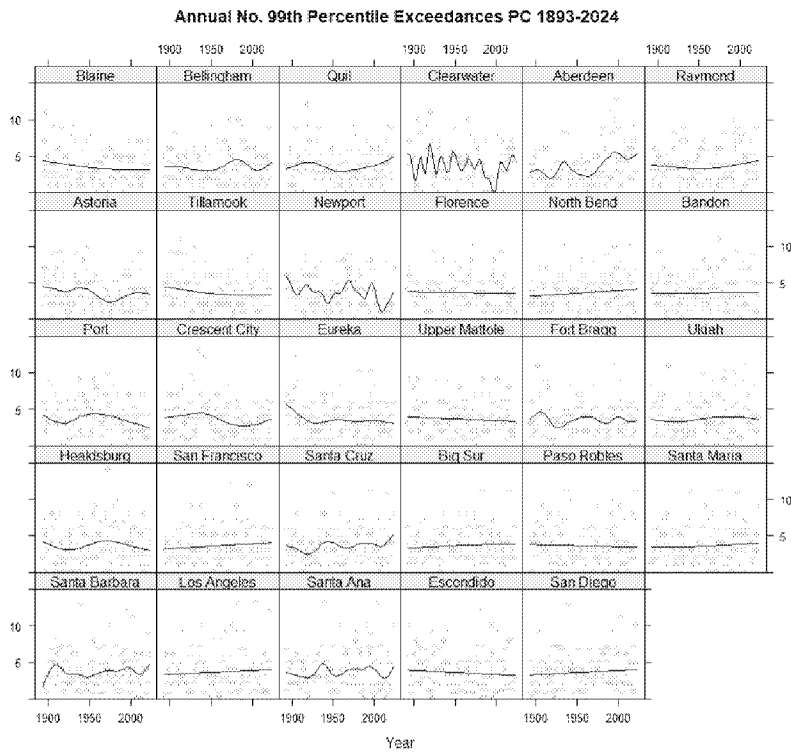
In the Midwest region nearly half the stations exhibit positive and significant trends in average precipitation since 1893 (23/61) and 1950 (28/61) but the trends weaken after 1980: only 6/61 locations are significant and the region-wide trend is insignificant. Regional trends in max and 99th percentile exceedances are insignificant post-1893 and -1980 but the latter are positive and significant post-1950.

In the Northeast region 12 out of 27 stations exhibit positive and significant increases in average precipitation post-1888, post-1950 and post-1980 (10/27) and the regional trend is positive and significant in all three intervals. The regional number of 99th percentile exceedances has a positive trend post-1950 and post-1980 but not post-1888. The significant positive trends post-1980 are concentrated in NH but are insignificant elsewhere.

Consequently, precipitation in the U.S. exhibits considerable regional and temporal variability. Relatively more places became wetter than drier. In the Midwest and Northeast the general pattern since 1950 favors increased precipitation depending on the location, although trends since 1980 have not tended to be statistically significant.

Data details in the following pages.

PACIFIC COAST



Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)

Number of 99 th pd exceedances	29	1	0	(-)
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(-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant

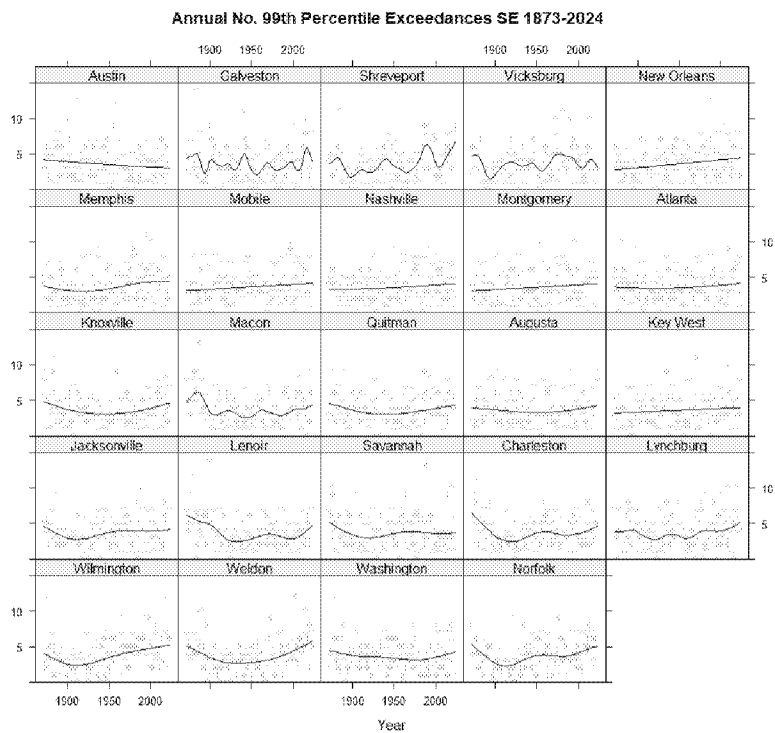
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pd exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pd exceedances	29	0	0	(+)

SOUTHEAST



Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

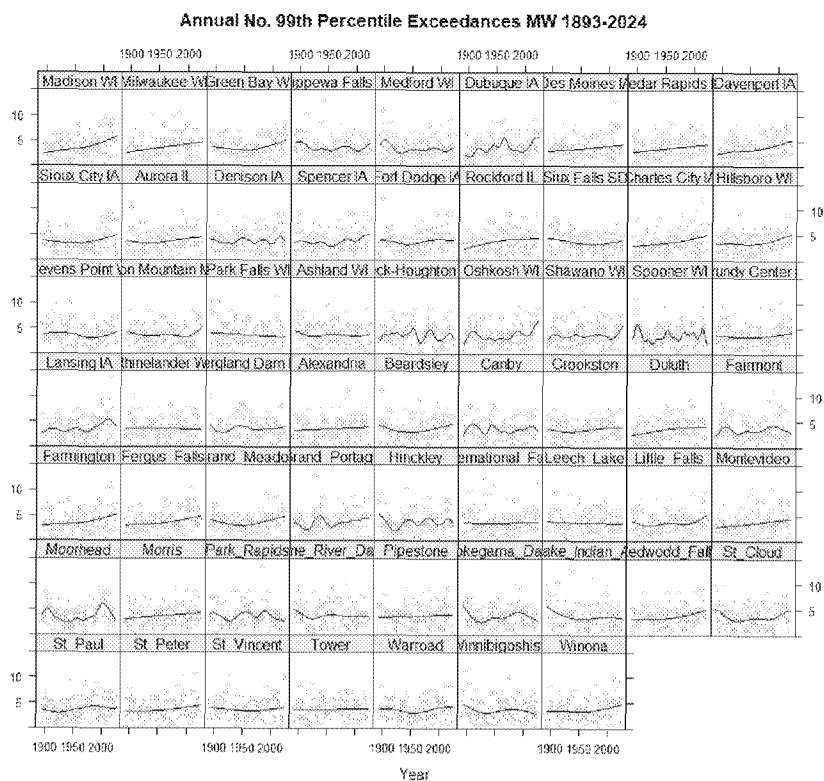
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

MIDWEST



Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

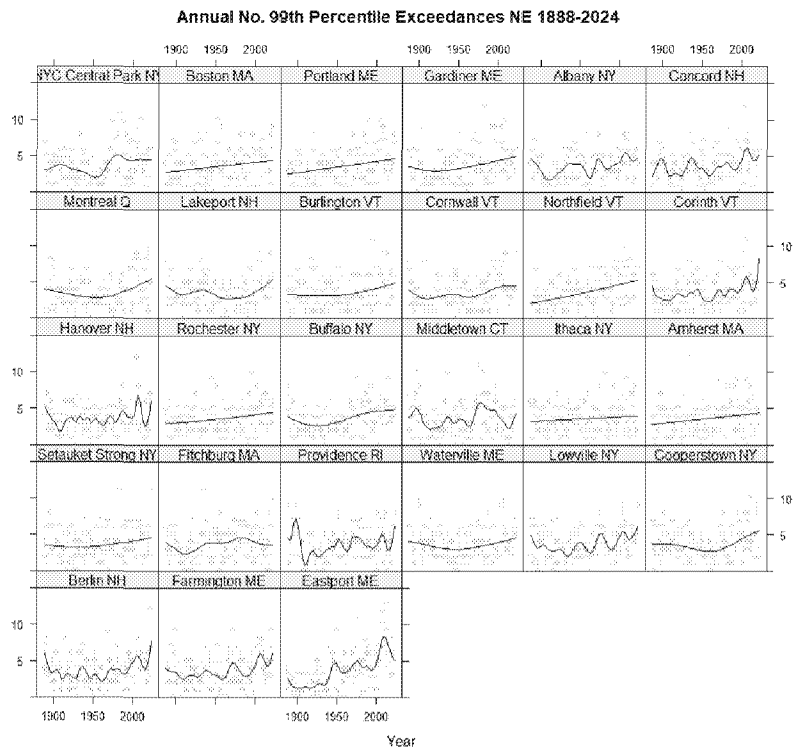
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

NORTHEAST



Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

Projections of Sea Level Rise [Curry]

The NCA5 states: "Global average sea levels over the past decade were also higher than in the preindustrial period by between 7 and 9.5 inches, with more than half of this rise occurring since 1980." The issue with the NCA5 is not related to observed levels of sea level rise, but rather to their projections to 2050 and 2100.

The sea level rise scenarios used in the NCA5 do not relate directly to the SSP emissions scenarios, but to specified amounts of sea level rise by 2100, whereby Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet). (Table 4 of Guide to Using this Report).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5

Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 6 for regional sea level information. Adapted from Sweet et al. 2022.”

Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

Considering only projections representing processes in whose quantification there is at least medium confidence, the IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m for the 5th–95th percentile range, for all scenarios ranging from RCP2.6 to RCP8.5. The IPCC AR6 cites values as high as 2.4 m at the upper end of the 95th percentile range for RCP8.5, if estimates include the hypothesized Marine Ice Cliff Instability (low confidence).

The range of sea level rise scenarios considered by the NCA5 includes Intermediate-High and High values associated with the implausible extreme emissions scenario RCP8.5 and processes in which there is low confidence in understanding. And neglects to include plausible lower scenarios, such as 0.2 m cited by the IPCC, that corresponds to the average rate of sea level rise over the past century.

Chapter 9 of the NCA states: "Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2)." These values of sea level rise encompass the Intermediate scenario to values slightly higher than the High scenario.

Global sea level rise projections to 2050 relative to a 2000 baseline can be evaluated with respect to the observed global sea level rise from 2000-2024, which is approximately 3.39 inches (0.28 feet).

[HYPERLINK "<https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level>"]

Hence it is inferred that NCA5 is projecting values of sea level rise between 2025 and 2050 that are 3.5 to 5.8 times the rate observed during 2000-2024.

Chapter 9 further states: "Looking toward the future, an 11 inch 28 cm average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches." This analysis accounts for the observed sea level rise between 2000 and 2020.

With regards to confidence levels, NCA5 Chapter 9 Traceable Accounts states: "There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050" Neither the statement nor the context in the paragraph does not distinguish as to whether this refers to global sea level rise, or US average sea level rise, although it is inferred to refer to global sea level rise.

In summary, the NCA5 presents future sea level rise scenarios that are not directly relatable either to SSP/RCP emissions scenarios or global warming levels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes for which there is low confidence. Projections to 2050 require rates of sea level rise during 2025 through 2050 that are more than three times the rate observed during 2020-2024. Further, the NCA5 ascribes high confidence to these sea level rise projections.

Hurricanes [Curry]

NCA5 Key message 2.2: “Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence).”

The justification for the *high confidence* conclusion on more rapid intensification of hurricanes is based on two citations. Kishatawa et al. (2012) examined data over the period 1986-2010 and Bhatia et al. (2019) considered satellite data on global hurricanes over a short period from 1982 to 2009 – short periods that are confounded by natural variability.

No justification for the *high confidence* conclusion on higher storm surge is provided in Chapter 2. The Knutson et al. (2019) assessment cited in Chapter 2 in a different context includes the following statement: “there is only low confidence for detection or attribution of an anthropogenic influence on the surge events.”

No justification is provided for the *high confidence* conclusion regarding hurricanes causing heavier precipitation. The Knutson et al. (2019) assessment cited in Chapter 2 in a different context includes the following statement: “However, no observational studies have provided convincing evidence of a detectable anthropogenic influence specifically on hurricane-related precipitation.”

In the Traceable Accounts section, Description of Confidence and Likelihood: “Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.”

In short, the NCA5 provides no observational basis for the *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges; instead they rely on basic

physical understanding and climate model simulations. The high confidence assertion regarding increasing rates of intensification is based on two papers with relatively short data records that are confounded by natural variability.

HURRICANE DAMAGE STUFF FORTHCOMING NOTES BELOW

hurricane damage in the United States has generally increased since 1900.¹⁵⁹
Changes in smaller-scale, short-lived severe weather

There has been a 17% decrease in the speed of movement of storms in the North Atlantic basin since 1900,¹⁵⁷ as well as an increased tendency for storms along the North American coast to meander and stall since the 1950s.¹⁵⁸

There is no long-term trend in the frequency of landfalling hurricanes in the United States since the late 19th century, but there has been an increase in basin-wide hurricane activity in the North Atlantic since the early 1970s.

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, In addition to recent increases in storm frequency, evidence continues to build that hurricanes are changing in other dangerous ways. Tropical cyclones have been intensifying more rapidly since the early 1980s,

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, leaving communities with less time to prepare. Hurricanes tend to lose energy as they move away from the ocean, but the rate of this hurricane decay has slowed since the 1960s, allowing storms to extend somewhat farther inland.¹⁵⁶ There has been a 17% decrease in the speed of movement of storms in the North Atlantic basin since 1900,¹⁵⁷ as well as an increased tendency for storms along the North American coast to meander and stall since the 1950s.¹⁵⁸ Slower-moving storms can result in more heavy rainfall, wind damage, storm surge, and coastal flooding; notably, after accounting for changes in the value of property and other assets placed in harm's way, hurricane damage in the United States has generally increased since 1900.¹⁵⁹

Knutson, T., S.J. Camargo, J.C.L. Chan, K. Emanuel, C.-H. Ho, J. Kossin, M. Mohapatra, M. Satoh, M. Sugi, K. Walsh, and L. Wu, 2019: Tropical cyclones and climate change assessment: Part I: Detection and attribution. *Bulletin of the American Meteorological Society*, 100 (10), 1987-2007. <https://doi.org/10.1175/ams-d-18-0189.1>

153. Vecchi, G.A., C. Landsea, W. Zhang, G. Villarini, and T. Knutson, 2021: Changes in Atlantic major hurricane frequency since the late-19th century. *Nature Communications*, 12 (1), 4054. <https://doi.org/10.1038/s41467-021-24268-5>

154. Bhatia, K.T., G.A. Vecchi, T.R. Knutson, H. Murakami, J. Kossin, K.W. Dixon, and C.E. Whitlock, 2019: Recent increases in tropical cyclone intensification rates. *Nature Communications*, 10 (1), 635. <https://doi.org/10.1038/s41467-019-08471-z>
155. Kishtawal, C.M., N. Jaiswal, R. Singh, and D. Niyogi, 2012: Tropical cyclone intensification trends during satellite era (1986-2010). *Geophysical Research Letters*, 39 (10). <https://doi.org/10.1029/2012gl051700>
156. Li, L. and P. Chakraborty, 2020: Slower decay of landfalling hurricanes in a warming world. *Nature*, 587 (7833), 230-234. <https://doi.org/10.1038/s41586-020-2867-7>
157. Kossin, J.P., 2019: Reply to: Moon, I.-J. et al.; Lanzante, J.R. *Nature*, 570 (7759), E16-E22. <https://doi.org/10.1038/s41586-019-1224-1>
158. Hall, T.M. and J.P. Kossin, 2019: Hurricane stalling along the North American coast and implications for rainfall. *npj Climate and Atmospheric Science*, 2 (1), 1-9. <https://doi.org/10.1038/s41612-019-0074-8>
159. Grinsted, A., P. Ditlevsen, and J.H. Christensen, 2019: Normalized US hurricane damage estimates using a reanalysis of total destruction, 1900-2018. *Proceedings of the National Academy of Sciences of the United States of America*, 116 (48), 23942-23946. [[HYPERLINK "https://doi.org/10.1073/pnas.1912277116"](https://doi.org/10.1073/pnas.1912277116)]

[[HYPERLINK "https://rogerpielkejr.substack.com/p/apples-oranges-and-normalized-hurricane?utm_source=publication-search"](https://rogerpielkejr.substack.com/p/apples-oranges-and-normalized-hurricane?utm_source=publication-search)]

[[HYPERLINK "https://journals.ametsoc.org/view/journals/apme/64/4/JAMC-D-24-0222.1.xml"](https://journals.ametsoc.org/view/journals/apme/64/4/JAMC-D-24-0222.1.xml)]

In summary, from a Type I error avoidance perspective, a slight majority of the authors (6 of 11) 631 had only low confidence that there has been a detectable decrease in global or western North 632 Pacific TC translation speeds since 1949. For the other five authors, four had low-to-medium 633 confidence, and one had medium confidence. Most authors (eight of 11) concluded that there 634 was only low confidence that anthropogenic forcing had contributed to the observed decrease. 635 Alternatively, from the perspective of reducing Type II errors, most authors (eight of 11) 636 concluded that the balance of evidence suggests there has been a detectable decrease in global

TC translation speeds since 1949; only one author concluded that the balance of evidence 638 suggests that anthropogenic forcing has contributed to the observed decrease.

RCP8.5 [Curry]

(not as simple as it seems, they rely a lot on critical warming levels)

Ambiguous Use of “climate change” [Koonin]

[text to come]

Misrepresentation of Historical Data [Koonin]

[Text to come]

Misrepresentation of the Potential of Wind/Solar Generation

[text to come]

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The Honorable Steven E. Koonin, Ph.D. is the Edward Teller Senior Fellow at Stanford's Hoover Institution. He has served as Under Secretary for Science at the Department of Energy (2009-2011), as Chief Scientist for British Petroleum (2004-2009), and as a professor at Caltech (1975 – 2004, the last nine years as Vice President and Provost). Koonin is a member of the National Academy of Sciences and the JASON group of government advisors, as well as a Governor of Lawrence Livermore National Laboratory, having served in similar capacities for the Los Alamos, Sandia, Brookhaven, and Argonne National Laboratories. Other prior roles include a University Professor at New York University, a non-resident Senior Fellow at the American Enterprise Institute, and a Trustee of the Institute for Defense Analyses, and Chair of the NASEM Divisional Committee for Engineering and Physical Sciences (201X-20XX). Koonin has a BS in Physics from Caltech and a PhD in Theoretical Physics from Massachusetts Institute of

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Ross McKittrick, Ph.D., is a Professor of Environmental Economics at the University of Guelph in Ontario, Canada. He holds a BA in economics from Queen's University, and an MA and Ph.D. in economics from the University of British Columbia. He has published widely in both economics and physical science journals on topics related to climate change, pollution and public policy. His book *Economic Analysis of Environmental Policy* was published by the University of Toronto Press in 2010. His background in applied statistics has led him to author or coauthor peer-reviewed publications across a wide range of topics in the physical sciences including paleoclimate reconstruction, malaria transmission, surface temperature measurement, climate attribution methodology and climate model evaluation. Professor McKittrick has made many invited academic presentations around the world, and has testified before the U.S. Congress and committees of the Canadian House of Commons and Senate.

Roy W. Spencer, Ph.D., is a Principal Research Scientist at the University of Alabama in Huntsville. He holds a BS in Atmospheric and Oceanic Science from the University of Michigan, and MS and PhD in Meteorology from the University of Wisconsin -Madison. Spencer's published research has focused on monitoring of weather processes and climate change from Earth-orbiting satellites, as well as using simple physical models for diagnosing climate sensitivity and climate feedbacks. As a NASA Senior Scientist for Climate Studies he served as the U.S. Science Team Leader for the Advanced Microwave Scanning Radiometer (AMSR-E) flying on the Aqua satellite, providing our most accurate global measurements of sea surface temperatures, sea ice, and several other features of the climate system. Along with Dr. John Christy, Spencer developed the first satellite-based technique for global temperature monitoring, for which they received NASA's Exceptional Scientific Achievement Medal and the American Meteorological Society's Special Award.

Review of the Fifth National Climate Assessment

[TOC \o "1-3" \h \z \u]

EXECUTIVE SUMMARY

This report critically evaluates the Fifth National Climate Assessment (NCA5), finding it an inadequate basis for climate and energy policies. A detailed review of the foundational chapters on climate science raises several key concerns:

Scientific Integrity

- An advocacy tone, particularly in the Overview chapter, inconsistent with scientific objectivity
- An endemic overconfidence when stating conclusions, including inflated certainty levels and overstatement of findings from underlying sources

Flawed methodology

- Use of *ad hoc* time scales for trend analyses in areas such as precipitation and heatwaves
- An overemphasis on extreme scenarios for future emissions
- Inadequate traceable accounts to support key conclusions

Deficient Review Process

- A review by the National Academy of Sciences, Engineering, and Medicine (NASEM) failed to challenge some fundamental flaws in NCA5
- The NCA5 authors failed to adopt some improvements recommended by NASEM

The report shows NCA5 to be a biased and incomplete picture of climate science that skews toward excessive climate risk. Consequently, NCA5 should not be used as basis for climate and energy policies.

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1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix 1) that we assess the suitability of the Fifth National Climate Assessment (NCA5 2023) for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, the National Academies of Science, Engineering and Medicine (NASEM) review of the Third Order Draft, and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, the Intergovernmental Panel on Climate Change (IPCC) and other organizations, as writers, reviewers and study leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science as of its publication in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted “CWG25”). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

To support our finding, the following sections of this chapter provide some background on the National Climate Assessments and the standards by which we have assessed NCA5. Chapters 2 through 6 detail important ways in which NCA5 fails to meet those standards. Chapter 7 then follows with an assessment of the NASEM review. Finally, Chapter 8 summarizes our evaluation of NCA5.

1.2 About the National Climate Assessments

The [[HYPERLINK "https://www.globalchange.gov/"](https://www.globalchange.gov/)] (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate “a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.

- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was an further expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis. NCA5’s self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (Section 1.4 below offers an example). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

Beyond the statutory requirements stated above, another pertinent standard is President Trump’s executive order of May 23, 2025, [[HYPERLINK "https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/"](https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/)]. It enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some scientists have found them controversial (Dellawalla et al. 2025).

Good climate and energy policies should balance the risks and benefits of a changing climate against the world’s growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have

a responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by operational demands and the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character, with greater uncertainties and hence need for expert judgement.

For those reasons, assessments of climate science that will be influential for policy making must include statements about the strength of knowledge. The IPCC's approach to assessing strength of knowledge is based on judgment of the available evidence and agreement among experts. But there are more sophisticated knowledge characterizations for risk management (Aven 2017). Here are its elements:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns

1.4 When Peer Review Fails

Peer review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, during the open review phases of early NCA drafts reviewers are volunteers who self-select what parts of the report to read, whereas the editors of academic journals recruit reviewers with relevant expertise and assign them to specific papers. As a result, there is no guarantee at that stage that any particular section of an NCA report was reviewed by anyone, let alone by someone with a perspective that differs from the authors. In fact, many potential reviewers have given up over the years because their input has systematically been ignored. The introduction of a NASEM review stage is at best a partial remedy for this. However, NCA authors have near complete authority whether to accept or reject review comments. By contrast, the Editor of an academic journal mandates the author to respond, and the reviewer and Editor assess its adequacy. Finally, the work of an NCA chapter author team is guaranteed to be published, whereas academic journals routinely reject papers that do not pass review.

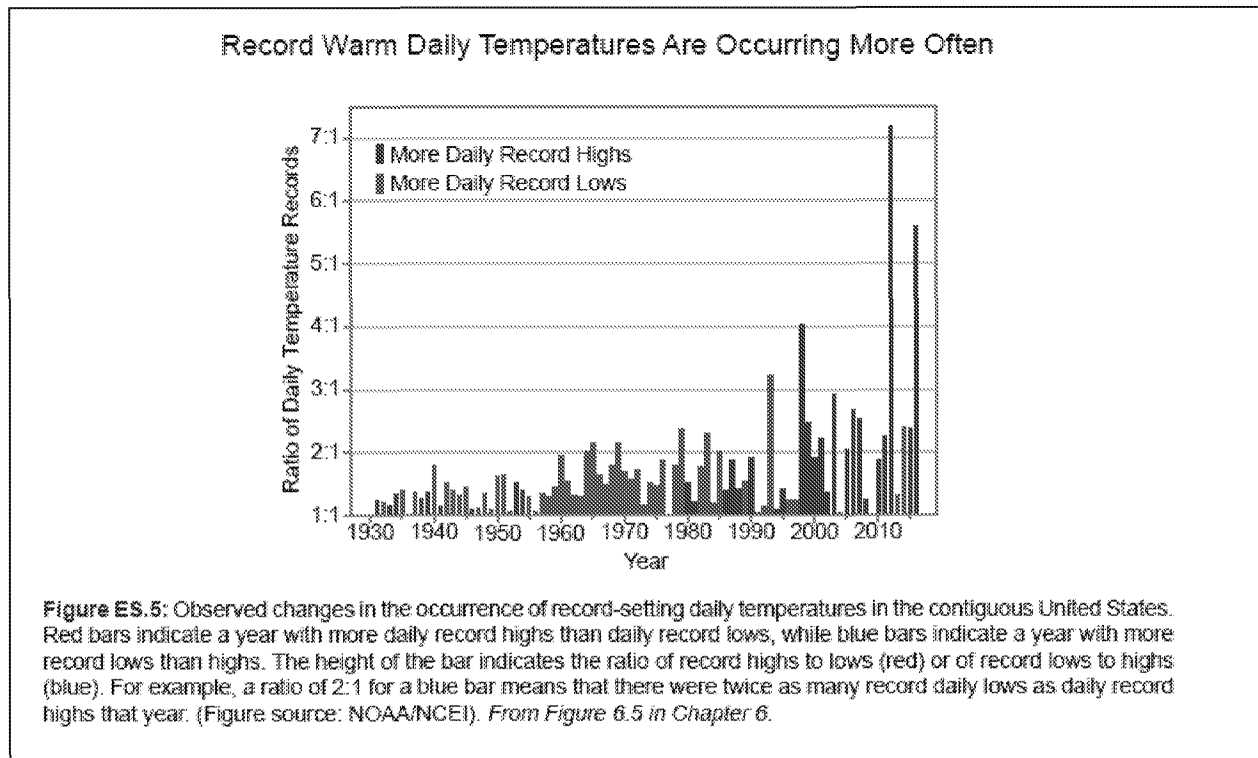
These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were “peer reviewed”. But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

As shown in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Considering cold and hot extremes together the U.S. the U.S. climate has become

more moderate over time. NCA4's Part I says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:

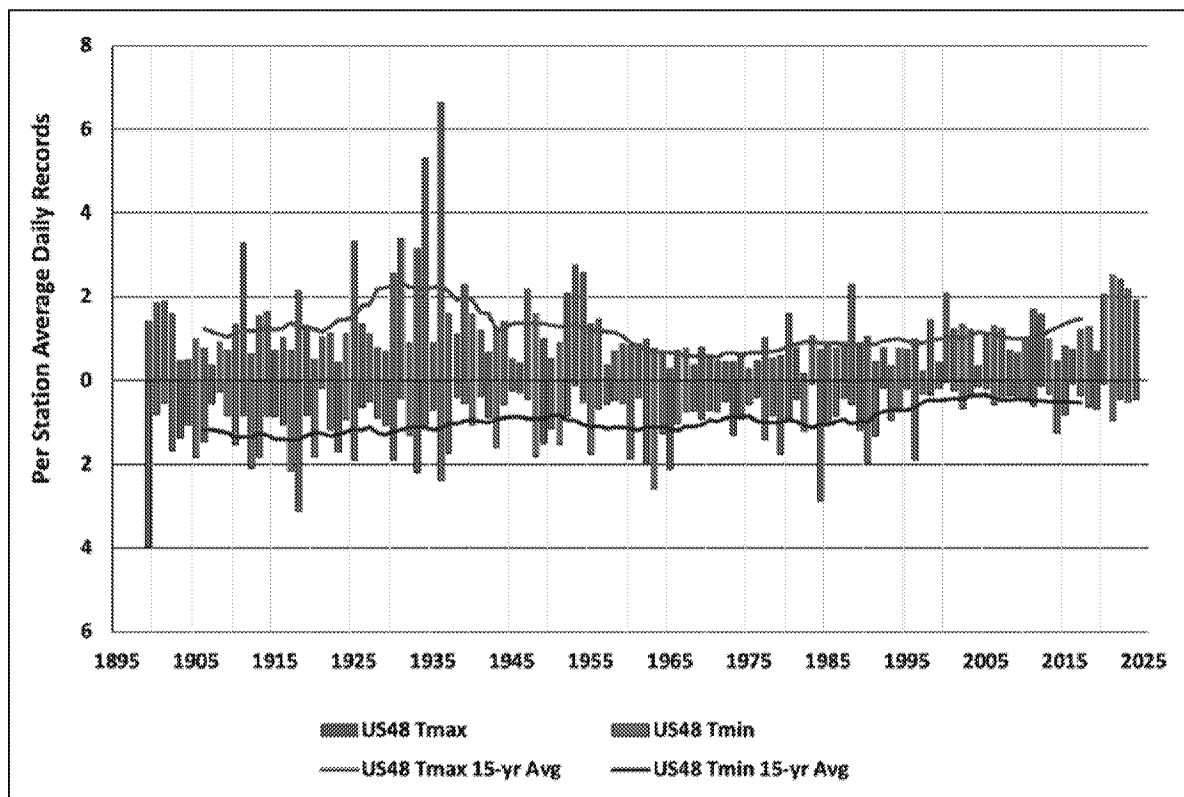


The figure appears to validate the claim that record warm daily temperatures are occurring more often. But the underlying data do not. Rather, they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as supported by Figure 6.4 deep within the CSSR itself (reproduced in our Section 4.2 below).

Figure ES.5 does not even show what its title implies, as it displays not simple counts of cold and warm extreme events, but rather ratios of the two counts. In fact, both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes increased. By graphing the ratio instead of counts, NCA4 creates a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis of the data – defining each record as the singular extreme in the sample interval, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the

CSSR was published in 2017. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the heat records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio of heat to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of NCA4 Figure ES.5.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3.

The National Academies' expert review panel [[HYPERLINK "https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report"](https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report)] the discussion of temperature extremes in a [[HYPERLINK "https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf"](https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf)] of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that

most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) [[HYPERLINK "https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf"](https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf)] to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The "new figure" referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies' panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn't have survived to publication. And the figure's problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

With this background we now present our critique of NCA5.

2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

NCA5 Chapter 1, "Overview", holds a prominent place in the Report since it summarizes the entire report and is the only section that many will read. Although the later chapters of NCA5 contain much sound scholarly content, Chapter 1 is marred by an activist tone and language that aggressively promotes mitigation policies. As such, this chapter adds an imprimatur of scientific authority to oversimplified declarations of opinion about public policy. Many examples can be cited; here we note a few that are particularly egregious.

Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic, that all warming is bad and causes economic damage, and that warming intensifies extreme weather. Such sweeping generalizations go well beyond what science has or can establish. The statement also refers to growing risks without saying whether they were large to begin with -- a small risk that grows may still be a small risk, and a large risk may be only incrementally worsened. A scientifically-sound version of this paragraph would instead say something like the following:

The Earth is warming because of a combination of natural and anthropogenic influences. This warming will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. Some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases might slow the warming although such policies have proven to be costly and disruptive, so any climate actions to be weighed against the potential benefits.

On the next page the Overview states:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits..."

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms; in fact, NCA5 Chapter 19 acknowledges that there will also be benefits. Nor is climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers.

Pages 8 and 9 of the Overview promote renewable energy options by noting, correctly, that the levelized costs of wind/solar generation have fallen sharply since 2010, and so offers this rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) significantly increases the cost of electricity. Further, there are yet unmet synchronization challenges in transmission grids with heavy penetration of wind and solar power. Here again it is advisory malpractice not to acknowledge these facts.

Page 14 of the Overview presents future emission scenarios with the following description: "Climate modeling experts develop global climate projections for a range of plausible futures." The word "plausible" is applied to all of the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The Figure does not compare observed emissions with previous projections nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as "plausible" the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline "business-as-usual" future.

Page 17 of the Overview introduces the discussion of risks from extreme weather events by saying "Harmful impacts from more frequent and severe extremes are increasing across the country." This

creates the impression that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the value of assets at risk it then invokes the NOAA Billion Dollar Dataset as evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product (Pielke Jr. 2024, 2025). Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends.

Page 23 of the Overview states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote alarm, but also the ineffectiveness of the review process in eliminating such statements.

3 OVERCONFIDENCE WHEN STATING CONCLUSIONS

3.1 Inflated certainty levels

Overconfidence in stating conclusions is an endemic problem in NCA5. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of NCA5 states that

confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.

and Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. An example is the conclusion about anthropogenic influence on climate change, arguably one of the most important scientific statements of the report.

Key Message 3.1 Traceable Account states:

There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.

while the corresponding statements from IPCCAR5 and AR6 are

AR5: It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together." (IPCC, 2013)

AR6: The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, AR5 refers to "*more than half* of the observed warming" and AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

3.2 Overstating findings in underlying sources

Although we did not do a detailed audit of NCA5's use of source material, spot checks turned up evidence of a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in some areas and attributes it to "climate change":

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The change metric in NCA5 Figure 2.4 is non-standard; we will discuss NCA5's inconsistent choices of time scales of analysis below. The claims were attributed to Knutson and Zeng (2018). But Knutson and Zeng did not say these things. They examined linear trends over 1901 – 2010, 1951 – 2010 and

1981 – 2010. They did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 – 1960, if only because their study was published in 2018. For 1981-2010, they noted stronger trends in some areas but cautioned that such changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States:

Observed annual precipitation trends over the recent 30-yr period 1981–2010 ([HYPERLINK "https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml" \l "fig5"]) have generally stronger magnitudes (in mm yr⁻¹ decade⁻¹) than observed trends for 1901–2010 or 1951–2010. This is as expected since trends over a shorter period have stronger potential for occurrence of pronounced temporary trends due to internal variability alone. Only 9% of the analyzed area has detectable and attributable anthropogenic influence (categories -3, -2, +2, +3), which represents less than one-third of the fractional areal coverage of such trends for 1901–2010 (29%). ... Eight percent of the analyzed area has attributable anthropogenic *increases* (categories +2, +3), including parts of eastern Europe, northern Asia, northern Australia/Maritime Continent, and tropical Africa.

As another example of overstating findings, NCA5's Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is allegedly attributed to two papers Diffenbaugh *et al.* (2018) and Kirchmeier-young and Zhang (2020). Diffenbaugh *et al.* presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not “robust” evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something that even IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using three GCMs, found

A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically.

However, they noted large differences among the three models in their simulated precipitation changes. Also, two of the three models failed to yield attribution for 5-day events for the North America mean. In other words the models disagreed on whether the observed changes were anthropogenic. Both cited references utilized the implausible RCP8.5 scenario and began their “historical” observational records only in 1961. Here again this is not “robust” evidence, it is merely suggestive, particularly since other studies have found natural variability predominant.

3.3 Technical example: Emergent constraints

Some of the overconfidence expressed by NCA5 arises by omitting discussion of counterevidence in the peer reviewed literature. An example is the topic of “emergent constraints”. Chapter 3 page 17 invokes this concept to support its claim that key uncertainties have been reduced:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as "emergent constraints." The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie GCM behavior to climate observations in hopes of generating insight into real-world equilibrium climate sensitivity to a doubling of carbon dioxide (ECS). Climate models exhibit a wide range of ECS values. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could examine whether the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a proliferation of proposed correlations with little physical motivation. As shown by Schlund *et al.* (2020) many emergent constraints patterned on CMIP5 models (Coupled Model Intercomparison Project No. 5, used for the IPCC 5th Assessment Report) failed to work on CMIP6 models (used for the IPCC 6th Assessment Report). In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the climate system. As a result, emergent constraints estimated on CMIP5 models increased the uncertainty of ECS, rather than narrowing it as intended and as claimed by NCA5.

Schlund *et al.* summarized the problem as follows [**boldface** used for emphasis]

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great "advance" that reduced uncertainty.

4 RELIANCE ON SHORT TIME PERIODS FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We provided examples from analysis of river flooding, heatwaves,

and extreme precipitation to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here are some examples of this problem from NCA5.

4.1 Average and Extreme Precipitation

McKittrick and Christy (2019) showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s, depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017). In CWG25 Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion; instead it refers to changes “since the 1950s”; NCA5 Figure 2.8 suggests 1958 might be the intended start date. Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

In addition to our concerns that inferences about trends are contingent on choice of time scale, we cannot reproduce the finding that positive trends are observed in extreme precipitation across all CONUS regions. We extended the data used in CWG25 (McKittrick and Christy 2025) to include 141 stations across the US in the Pacific Coast, Midwest, Northeast and Southeast regions (Christy 2025). See details in Appendix 3. Many post-1950 trends are positive but statistically insignificant depending on the measure of extreme precipitation. It is possible to find locations that support the NCA5 position, such as the Southeast post-1950, but results are not robust to selecting longer or shorter time scales of analysis nor do they generalize across all regions.

The following is a more accurate summary of what U.S. data show.

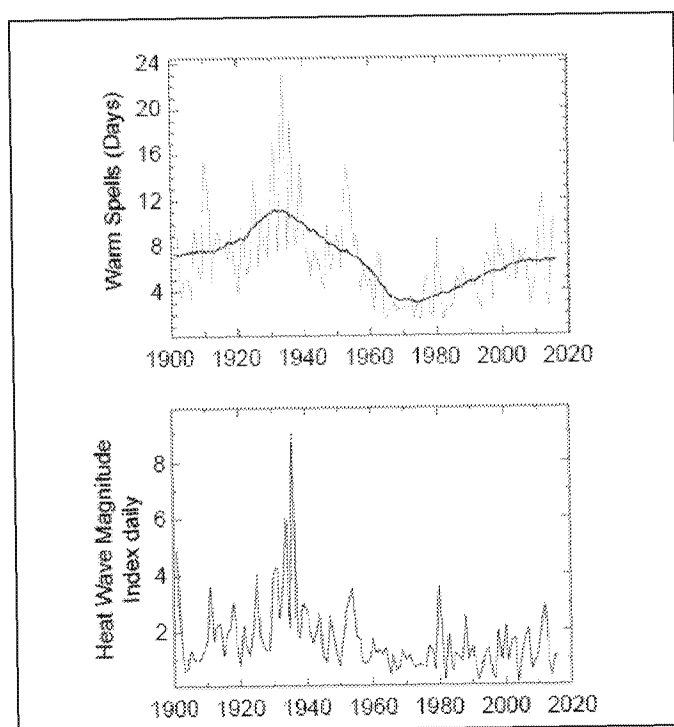
There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution of changes in precipitation to anthropogenic warming difficult.

4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the entire 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies:

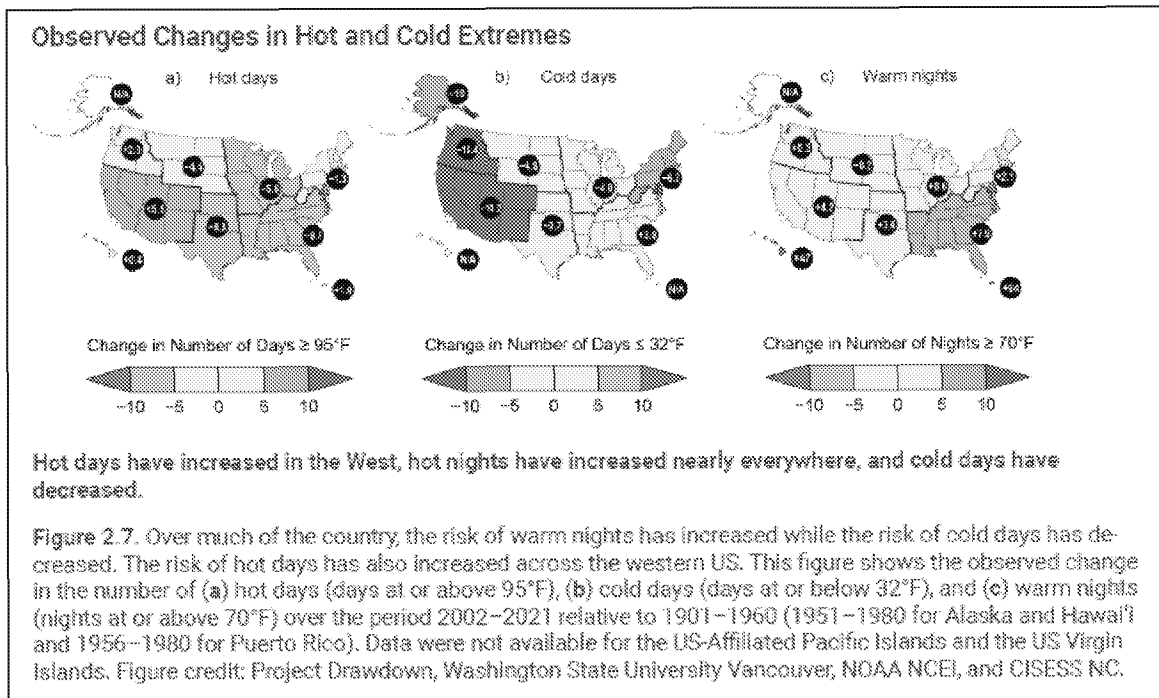
[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s. (NCA4 pp. 190-191)



U.S. Heat waves since 1900. Source: NCA4 Figure 6.4

Contrast this careful and factual language with NCA5 Key Message 2.2: “Extreme Events Are Becoming More Frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 (reproduced below) which shows the number of hot days, cold days and warm nights (respectively in panels a—c) over the period 2002-2021 compared to 1901-1960. [Presumably these are annual counts, although not stated in the caption.]



Close inspection shows that this figure contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of NCA4. Notwithstanding Key Message 2.2 the leftmost panel in Figure 2.7 above shows that over most of CONUS the number of extreme heat days has decreased in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted as it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 chapter 2 elaborates on Key Message 2.2 by saying (page 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But while it mentions the increase in hot days in the West NCA5 fails to mention the decrease everywhere east of the Rockies. On the next page (page 17) it raises the comparison to the 1930s then switches to discussing global counts:

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

The reference to a global trend seems to be an attempt to tie heatwaves to anthropogenic climate change. But the obvious question, unaddressed by NCA5, is why one region follows the global pattern of increasing heatwaves while most of the country is trending in the opposite direction. These issues are addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by natural variability than by the small anthropogenic forcing. The analysis in CWG25 shows that for both (a) hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is no hotter than a century ago in the U.S. Thus, the NCA5 claim that

“multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal and spatial domains to encompass all available data (Chapter 6 and Figure 6.3.6 of CWG25).

NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG2025 Section 8.6.1 discussed this event in detail, reviewing the multiple peer reviewed studies that explained the unusual meteorological context was unrelated to human-caused climate change, a point omitted from the NCA5 discussion.

NCA5 finally addresses the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator ([[HYPERLINK "https://www" \].globalchange.gov/indicators/heat-waves](https://www.globalchange.gov/indicators/heat-waves)) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed part of NCA5 in CWG25 Section 6.3. The figure referenced by NCA5 uses an *ad hoc* definition of heat wave, namely two consecutive days with minimum nighttime temperatures above the 85th percentile, and an *ad hoc* time scale which begins in the 1960s, the coldest decade in the last century, thus suppressing any comparison to the 1930s. Further, nighttime temperatures in urban areas have increased faster than daytime temperatures (which NCA5 acknowledges), but this is a signature of urban heat islands and not a good metric of climate change. CWG25 noted as well that the occurrence of hot days ($\geq 95^{\circ}$ F) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

5 INADEQUATE TRACEABLE ACCOUNTS

NCA3 began the practice of including a section on Traceable Accounts at the end of each chapter. This is the description from NCA5:

Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team’s expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.

The Traceable Accounts for each Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts could have addressed the statutory requirement that the NCA discuss scientific uncertainties. They could also help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5's Chapters 2 and 3 are uneven, often superficial and uninformative.

An example of a deficient Traceable Account is NCA5's Key Message 2.2: "Extreme Events are Becoming More Frequent and Severe". The "Description of the Evidence Base" offers two paragraphs, the first summarizing the findings and the second generically describing the types of data that can be used for storms. "Major Uncertainties and Research Gaps" focuses on the uneven distribution across U.S. populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data apart from reanalysis products.

But the most astonishing deficiency is in the "Description of Confidence and Likelihood." One of the statements in Key Message 2.2 is:

Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence).

The Description of Confidence and Likelihood includes the following statement:

Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.

No reference to journal publications or a specific data set is made anywhere in the Chapter regarding hurricane-induced precipitation or storm surge to support this *high confidence* conclusion.

The Traceable Accounts for the various Key Findings of Chapter 3 have some substantial inconsistencies. Consider

Key Message 3-1: Human activities have caused global warming.

Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

The Uncertainties section addresses only uncertainties in radiative forcing by greenhouse gases. In contrast, the Traceability Analysis of Key Message 3-4 ("Humans Are Changing Earth System Processes") raises the problem that relatively little is known about the role of natural variability at the regional scale. From its Description of Evidence Base:

In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals.

And from its Major Uncertainties and Research Gaps:

For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.

These statements are among the most scientifically credible in the entire NCA5 and they directly undercut the confidence assigned to Key Message 3-1.

There is also a generic problem in tracing NCA5's Traceable Accounts. The Front Matter of NCA5 states:

Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.

Clicking on the eyeball icon does not reveal the metadata information, instead a "Contact Us" email appears, addressed to the USGCRP. This is clearly an inadequate way to archive the metadata information.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.

6 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to "project major trends for the subsequent 25 to 100 years," NCA5 relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. The IPCC AR6 published in 2021 stated that "The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments." and that same year UN Climate Negotiators (COP) stopped using scenarios above 4.5.

NCA5 makes the following observations about the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue, NCA5 otherwise ignored the problem. A keyword search of NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, nine NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios.

The problem of relying on extreme scenarios is particularly acute for NCA5's sea level rise projections. The sea level rise scenarios used in NCA5 do not relate directly to the SSP emissions scenarios, but rather to specified amounts of sea level rise by 2100. Table 4 of NCA5's "Guide to Using this Report" reproduced below shows that Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5						
Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawai'i and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2022."						
Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

Table 4 from the Front Matter of NCA5

Considering only projections representing processes quantified with at least medium confidence, IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m (5th—95th percentile range). Nevertheless, the range of sea level rise scenarios considered by NCA5 extends to 2.0 m. Further, NCA5 fails to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which also corresponds to the average rate of sea level rise over the past century.

Chapter 9 of NCA5 offers the following predictions of sea level rise:

"Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2)."

These values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the [[HYPERLINK "https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level"](https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level)] global sea level rise from 2000-2024, approximately 3.39 inches (0.28 feet). NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000-2024, an exceedingly implausible outcome. Chapter 9 further states:

“Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches.”

...

“There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050”

In summary, NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios nor to global warming levels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes in which there is low confidence. Projections to 2050 require rates of sea level rise from 2025 to 2050 that are more than triple the rate observed during 2000-2024. Further, NCA5 ascribes *high confidence* to these sea level rise projections. CWG25 Section 7.3 provides further context for USGCRP projections of extraordinary sea level rise in the next 25 years.

More generally, NCA5’s inclusion, and even focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 CONFLATION OF NATURAL AND ANTHROPOGENIC CLIMATE CHANGES

NCA5’s Glossary defines “climate change” as a change in climate for any reason. This is technically correct, but at variance with the (now) popular perception of all climate changes being anthropogenic. The distinction is not academic- it is central both to attribution questions and to projections, since anthropogenic changes would respond to mitigation, while natural changes are unavoidable.

The discussion on NCA5 page 2-4 begins “Human activities are changing the climate”, then goes on to list evidence for anthropogenic GHG emissions and climate warming. The next paragraph begins “Climate change is happening now in the United States. Including Alaska, the continental US has been warming about 60% faster than the planet as a whole since 1970.” In context the implication is that the warming of CONUS faster than the planetary average is an effect of GHG emissions. But it is an artifact of the Earth’s surface being 70 percent ocean. Since the ocean warms more slowly than land, comparison of any land surface outside the tropics with the global average would show the land surface to be warming faster than the global average, regardless of the cause of the warming.

The same page goes on to say “Climate change is already affecting people in the United States. Extreme heat was estimated to be responsible for more than 700 deaths per year between 2004 and 2018 although some estimates put heat-related mortality closer to 1,300 deaths annually.” But extreme heat, whether naturally-caused or not, has always been a risk to human health. As to trends,

the data show that adaptation has caused the mortality burden of extreme heat to drop substantially in recent decades (CWG25 Section 10.3.1).

Consider also the NCA5 statement on precipitation that we cited in Section 3.2:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The attribution is superfluous because the statement is a tautology by NCA5's definition of climate change. But its gratuitous inclusion effectively attributes the observed trend to greenhouse gas emissions.

Exploitation of the ambiguity in "climate change" is endemic to NCA5. The NASEM review (pp. 23-24) commented on this problem, and it could have been easily addressed by adopting the phrase "changing climate" for general changes while reserving the term "climate change" for anthropogenic changes. But the NCA5 authors seemingly ignored their recommendation.

A separate but related issue is use of the term "climate change" to refer to increases in socioeconomic vulnerabilities that have anthropogenic but non-GHG-related causes. NCA5 page 1-19 states "Climate change exacerbates inequalities." But the issue discussed is the negative correlation between neighborhood-level income and land surface temperatures (LST) in urban areas. To the extent the correlation is real the most likely explanation is that low-income households concentrate where housing is less expensive, which may be in neighborhoods with less nearby parkland and tree cover, which has nothing to do with CO₂ emissions. Similarly the NCA5 makes repeated reference to the Billion Dollar Disaster dataset which is dominated by trends in population and economic growth, as we discussed in CWG25 Section 10.2.

8 SUMMARY EVALUATION OF NCA5 AND RECOMMENDATIONS FOR NCA6

This chapter summarizes our evaluation of NCA5 relative to OSTP's charge: whether NCA5 (1) complied with the USGCRP's statutory obligation; (2) adheres to the core tenets of Gold Standard Science; and (3) can suitably inform federal climate and energy policy. The points made in this summary analysis refer to specific sections of this report as well as to the CWG25 report.

8.1 Compliance with USGCRP's statutory obligation

As cited in Section 1.2 of this report, the Global Change Research Act requires an assessment that:

- (1) integrates, evaluates, and interprets the findings of the [Global Change Research] Program and discusses the scientific uncertainties associated with such findings;
- (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

We deem NCA5 to have fallen short when evaluated against these criteria because of the following major shortcomings (each is detailed in the chapters cited):

- Inadequate assessment of the relevant topics in climate science and the hazard components of climate impacts. NCA5 instead focuses on evaluation of societal vulnerabilities, “Climate Action,” and policy recommendations with a social justice emphasis (Section 1.2).
- Overconfidence in conclusions and inadequate assessment of uncertainties (Section 3.1.5)
- Inadequate discrimination between natural and human-induced causes of trends and impacts (Chapter 7)
- Inadequate analysis of climate trends by relying on short time periods (Chapter 6)
- Uncritical evaluation of emission scenarios and climate simulations in making projections for the next 25 to 100 years (Chapter 6; Section 3.2.1 and Chapter 5 of CWG25).

8.2 Adherence to the tenets of Gold Standard Science

With respect to the tenets of Gold Standard science listed in Section 1.2 of this report, we have identified the following major shortcomings in NCA5:

- **Lack of reproducibility.** In the few examples that we examined closely, we identified an instance where we could not reproduce the findings of the NCA5, a task that should require only rudimentary data analysis (Section 4.1)
- **Lack of transparency.** In many instances, the Traceable Account fails to justify the Key Finding. Metadata was not readily accessible. (Chapter 5)
- **Inadequate communication of error and uncertainty.** The Traceable Account for each Key Message provides a section on Major Uncertainties and Research Gaps; most of the accounts that we examined were superficial and uninformative. (Chapter 5)
- **Not skeptical of findings and assumptions.** The main text of the chapters is, with few exceptions, not skeptical of its findings and assumptions. (Chapters 3, 5)
- **Some hypotheses and Key Messages are not falsifiable.** Key Message 13.4 is but one of many examples: “Equitable Distribution of Transportation Trade-offs and Benefits Requires Community Involvement.”
- Failure to acknowledge benefits of warming and additional atmospheric CO₂ (CWG25 Section 2.1, Chapter 9)
- **Inadequacy of the peer review process.** The review of the NCA5 Third Order Draft by National Academies of Science, Engineering and Medicine (NASEM) identified some of the deficiencies we have noted, but the NCA5 authors were not obligated to adopt the NASEM recommendations. More importantly, we’ve identified many other deficiencies in NCA5; the NASEM review did not point them out and thus lacked the rigor expected of Academies’ reports. (Section 1.4, Chapter 7)

8.3 Suitability for informing Federal climate and energy policy

We assess that the selection and presentation of information in NCA5 makes it an unreliable basis for U.S. climate and energy policymaking. For each of the elements of knowledge characterization suitable for risk management listed in Section 1.3, here are specific examples where NCA5 falls short:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge

- NCA5 focused on implausibly extreme scenarios for emissions and sea level rise scenarios and made policy recommendations without adequate consideration of the costs
- The degree to which data/information exists and are reliable and relevant
 - NCA5's assumptions about model reliability, and its use of short time periods for analysis, does not support its high-confidence conclusions
- The degree to which there is disagreement among experts, including those from different environments or academic fields
 - While NCA5 was an interdisciplinary effort, the concerns we have raised all point to a failure to canvass or communicate the full range of evidence including data and research findings that speak against Key Messages.
- The degree to which the phenomena involved are understood and accurate models exist
 - NCA5 is not appropriately skeptical of the ability of climate models to attribute the causes of warming and extreme events or to project future climates
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns
 - A major NCA5 shortcoming is its dismissal of natural climate variability in many contexts where it should have been a major consideration

NCA5 is also problematic for informing policy because its hyperbolic language promotes alarm and advocates for specific policies without proper analysis of marginal costs and benefits. In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to “save the planet.” The NASEM Review of the NCA5 underscores the endemic nature of this problem - their review appears to be written by authors who share many of the biases of the NCA5 team, with an inordinate focus in the review on social and policy issues. It is then not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public’s right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem forty-five years ago in an [[HYPERLINK "https://science.sciencemag.org/content/208/4448/1093"](https://science.sciencemag.org/content/208/4448/1093)] that still resonates:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

8.4 Recommendations for NCA6

While we have assessed NCA5 to be scientifically inadequate and unsuitable as a basis for decision-making, one can imagine a different National Climate Assessment that meets statutory and policymaker requirements. The goal should be not to persuade, but to impart understanding by being transparent and complete. A suitable NCA would be an important complement to IPCC work; to the extent that its conclusions differed from the oracular “consensus” of the IPCC reports and additional topics are addressed, it would promote a more open scientific discussion and a more informed policy debate.

We recommend that the NCA6 have a narrower scope than NCA5, refocusing on climate science, including natural climate variability, with topics to include:

- How the climate has changed, or not, in the distant and recent past
 - The U.S. has the best and longest meteorological records and they should be displayed in their entirety. Trend analyses should include longest periods available and employ suitable statistical methods. Local paleoclimate data should be considered where available. Analysis would demonstrate not only how the climate has changed, but also regional heterogeneity. Standard, easily understandable metrics should be employed.
- The range of climatic and weather conditions, including weather extremes, that can reasonably be expected to occur in U.S. regions over the near future for which planners and policymakers should be prepared.
- A critical survey of current global and regional modeling capabilities and their suitability for regional impact assessments and projections. This would include an assessment of their ability to reproduce observed changes. It would also discuss alternative methods where feasible for generating projections and forecasts on regional and decadal scales.
- Assessment of the impacts of recent historical climate variability and change on ecosystems and society. Where long-term data indicate a detectable trend of a regional change, regional projections using climate models and storyline approaches can be used, targeted at the period 2030-2050. Emissions scenarios exceeding RCP4.5/SSP2-4.5 and models with ECS values exceeding 4°C should not be used

It would also be important to work at a level of detail appropriate to current science capabilities. The pressures toward spatially or temporally precise projections should be resisted as the current models are nowhere up to the task (an example is discussed in CWG25 Section 5.8). In that light, the many pages of NCA5 devoted to regional and sectoral impacts have little value. It would have been simpler and more accurate to say “we can’t predict at that level.” [Does this contradict the second bullet above?]

Given the substantial deficiencies in NCA5 that we have outlined, along with the endemic bias of the climate community towards alarmism and policy advocacy, producing NCA6 with the current NCA organizational construct would be a challenge. A NASEM review could help, but only if the selected participants reflect full viewpoint diversity and do not simply mirror the assumptions and biases of past NCA teams. We believe the CWG25 report to be a good start on NCA6 in terms of coverage, depth, and tone.

More broadly, we recommend a rewrite of the Global Change Research Act. The current mandate is vague and off point, allowing successive NCA teams to reinterpret the mandate as they see fit. Moreover, it is becoming increasingly clear that current and foreseeable models are not fit-for-purpose to describe regional climates, let alone usefully project them for 25 and 100 years. And the use of the term “global change” is ambiguous and outdated.

9 REFERENCES

- Aven, Terje (2017) "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices," *Reliability Engineering & System Safety* 167 (November 2017): 42–48 [[HYPERLINK "https://www.sciencedirect.com/science/article/pii/S0951832016306950"](https://www.sciencedirect.com/science/article/pii/S0951832016306950)]
- Climate Working Group (2025) Impacts of Carbon Dioxide Emissions on the U.S. Climate. Washington DC: Department of Energy, May 27, 2025.
- Dellawalla, Colette, Victor Ambrose, Carl Bergstrom *et al.* (2025) "Trump's new 'gold standard' rule will destroy American science as we know it." *The Guardian* May 29, 2025 [[HYPERLINK "https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science"](https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science)]
- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. <https://doi.org/10.1126/sciadv.aao3354>
- Handler, Philip (1980) Public Doubts About Science. *Science* 208(4448) p. 1093 [[HYPERLINK "https://www.science.org/doi/10.1126/science.208.4448.1093"](https://www.science.org/doi/10.1126/science.208.4448.1093)]
- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308-13313. <https://doi.org/10.1073/pnas.1921628117>
- Knutson, Thomas and Fanrong Zeng (2018) "Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends" *Journal of Climate* 31(12) [[HYPERLINK "https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml"](https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml)]
- Koonin, Steven (2024) *Unsettled: What Climate Science Tells Us, What It Doesn't, and Why It Matters*. ---: ---
- McKittrick, R., and J.R. Christy (2019). Assessing changes in US regional precipitation on multiple time scales. *Journal of Hydrology*, 578, 124074. [[HYPERLINK "https://doi.org/10.1016/j.jhydrol.2019.124074"](https://doi.org/10.1016/j.jhydrol.2019.124074)]
- McKittrick, R., and J.R. Christy (2025), "Data and Code for DoE Report 2025", Mendeley Data, V1, doi: 10.17632/8n9ks93vn7.1
- National Academies of Sciences, Engineering, and Medicine. 2023. *Review of the Draft Fifth National Climate Assessment*. Washington, DC: The National Academies Press. [[HYPERLINK "https://doi.org/10.17226/26757"](https://doi.org/10.17226/26757)]
- NCA4. (2017). *Climate science special report: Fourth National Climate Assessment, Volume I* (D. J. Wuebbles, D. W. Fahey, and K. A. Hibbard, Eds.). U.S. Global Change Research Program. [[HYPERLINK "https://doi.org/10.7930/J0J964J6"](https://doi.org/10.7930/J0J964J6)]
- NCA5. (2023). *Fifth National Climate Assessment* (A. R. Crimmins *et al.*, Eds.). U.S. Global Change Research Program. [[HYPERLINK "https://doi.org/10.7930/NCA5.2023.CH1"](https://doi.org/10.7930/NCA5.2023.CH1)]
- Pielke Jr., R. (2024). Scientific integrity and U.S. 'billion dollar disasters'. *npj Natural Hazards*, 1, Article 12. [[HYPERLINK "https://www.nature.com/articles/s44304-024-00011-0"](https://www.nature.com/articles/s44304-024-00011-0)]
- Pielke Jr., R. (2025, May 8). RIP NOAA's billion dollar disasters. The Honest Broker [Substack]. [[HYPERLINK "https://rogerpielkejr.substack.com/p/rip-noaas-billion-dollar-disasters"](https://rogerpielkejr.substack.com/p/rip-noaas-billion-dollar-disasters)]
- Schlund, Manuel, Axel Lauer, Pierre Gentine, Steven C. Sherwood, and Veronika Eyring (2020) Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6? *Earth System Dynamics* 11 1233-1258 [[HYPERLINK "https://doi.org/10.5194/esd-11-1233-2020"](https://doi.org/10.5194/esd-11-1233-2020)]

APPENDICES

APPENDIX 1: Charge to the review

APPENDIX 2: Reproducibility of NCA5 claim of extreme precipitation trends

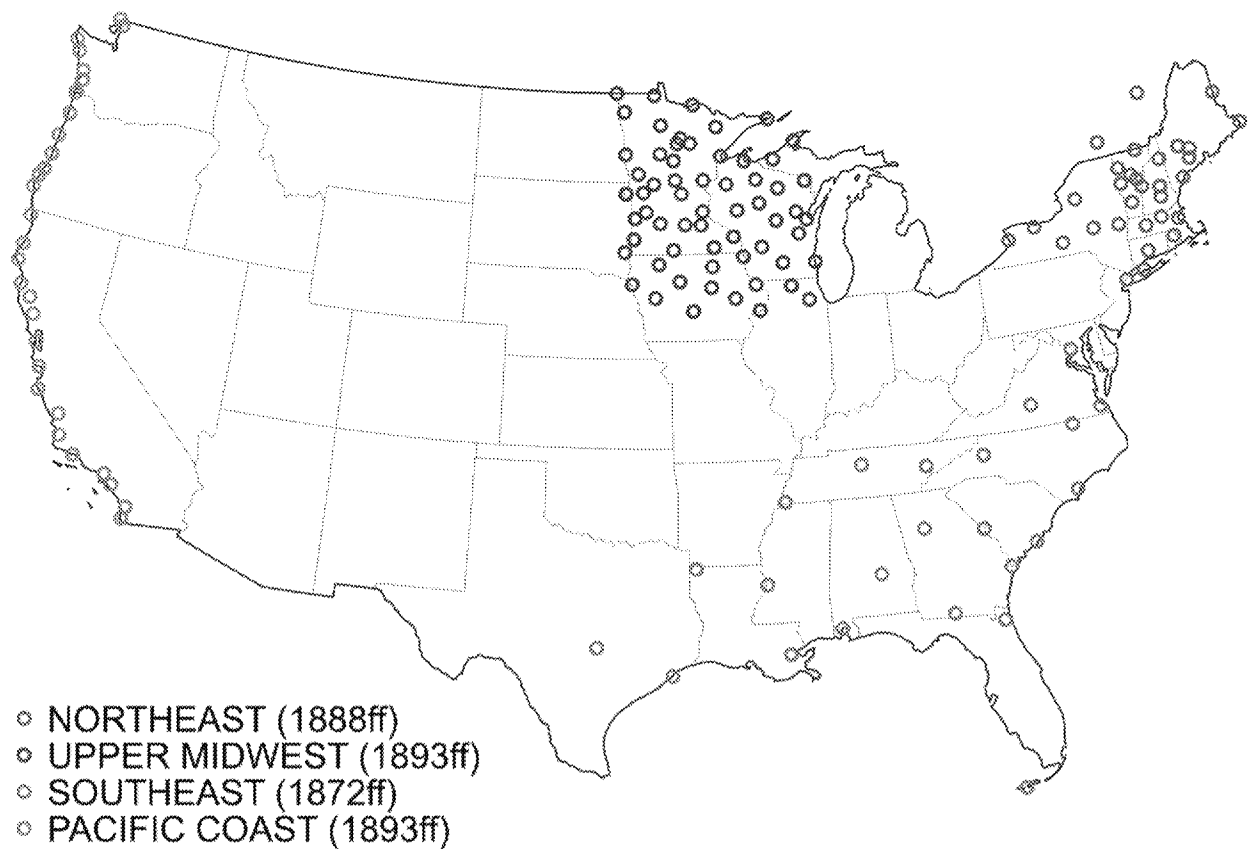


Figure A1: Stations used in the following analyses

Note: All data are available at Christy (2025). Methods as described in McKittrick and Christy (2019), code available at McKittrick and Christy (2025).

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure
Column 2: Number of stations in that region
Column 3: Count of stations exhibiting a significant positive trend
Column 3: Count of stations exhibiting a significant negative trend
Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)
Number of 99 th pct exceedances	29	1	0	(-)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

ABOUT THE AUTHORS

[Insert updated bios]

Review of the Fifth National Climate Assessment

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1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix XX) that we assess the suitability of the Fifth National Climate Assessment for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, NASEM review of the Third Order Draft and the USGCRP responses to the review. We have drawn upon our long experience working on advisory reports, including for the NASEM, IPCC and other organizations, as writers, reviewers and project leaders.

Our report begins with background on the National Climate Assessments. We then discuss the standards by which we have assessed NCA5, followed by specific deficiencies that we have identified

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of the science as of its publication date in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted "CWG25"). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

1.2 About the National Climate Assessments

The [HYPERLINK "<https://www.globalchange.gov/>"] (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change, but also sought to identify potential adaptation measures and identify the highest priorities for future research.
- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National

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Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.

- NCA4 (2017/2018) was an expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis. NCA5’s self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points. Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

In Appendix XX we include a letter of guidance from the Office of General Counsel, U.S. Department of Energy, summarizing the extent of statutory requirements governing USGCRP work products in general and NCA products in particular.

We can summarize the standards applicable to the NCA as follows:
- details.

Beyond the statutory requirements we draw attention to two other pertinent standards. President Trump’s executive order of May 23, 2025, “[[HYPERLINK "https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/"](https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/)]" enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some have found them [[HYPERLINK "https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science"](https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science)].

When scientific reports are being assembled that will be highly influential on climate policymaking there are other desiderata, including statements about the strength of climate knowledge. The IPCC's approach is based on judgment of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include (Aven 2017)¹:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns

Good climate and energy policies will balance the risks and benefits of a changing climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a unique responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.

In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to "save the planet." So it is not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.

In 1980, Philip Handler, then-President of the National Academy of Sciences Philip Handler, identified the problem in a 1980an editorial² that resonates eerily four decades later:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

¹ Aven, Terje (2017) "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices," *Reliability Engineering & System Safety* 167 (November 2017):42-48 [HYPERLINK "<https://www.sciencedirect.com/science/article/pii/S0951832016306950>"]

² Handler, Philip (1980) Public Doubts About Science. *Science* 208(4448) p. 1093 [HYPERLINK "<https://www.science.org/doi/10.1126/science.208.4448.1093>"]

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1.4 When Peer-Review Fails

Peer-review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, NCA reviewers self-select on a volunteer basis whether to provide comments and what parts of the report to read, whereas in academic journals Editors recruit reviewers and assign them to specific papers. There is no guarantee that any particular section of an NCA report was reviewed by anyone, let alone by someone with a different perspective than the authors. This is a problem with NCA and IPCC reports since over the years many potential reviewers have given up making the effort, because their input has systematically been ignored. Second, NCA authors have near complete authority whether to accept or reject review comments. Here, for example, is how a review comment critical of a section of the NCA5 draft was handled by the authors:

By contrast in academic journals the Editor mandates the author to respond and the reviewer gets to assess its adequacy. Once an NCA chapter author team has been selected publication of their work is guaranteed, whereas academic journals routinely reject papers if they do not pass review.

These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were “peer reviewed”. But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a Figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

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As we pointed out in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Considering cold and hot extremes together the U.S. the U.S. climate has become more moderate over time. NCA4’s Part I ([HYPERLINK “https://science2017.globalchange.gov/”], CCSR) says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:

Record Warm Daily Temperatures Are Occurring More Often

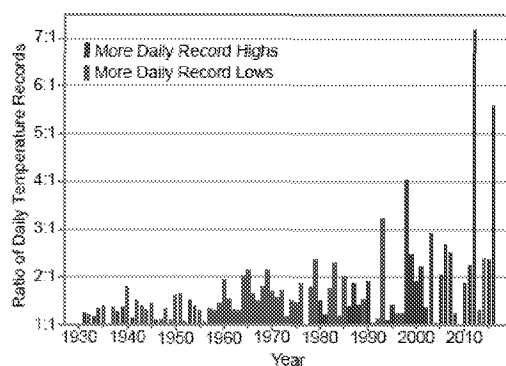
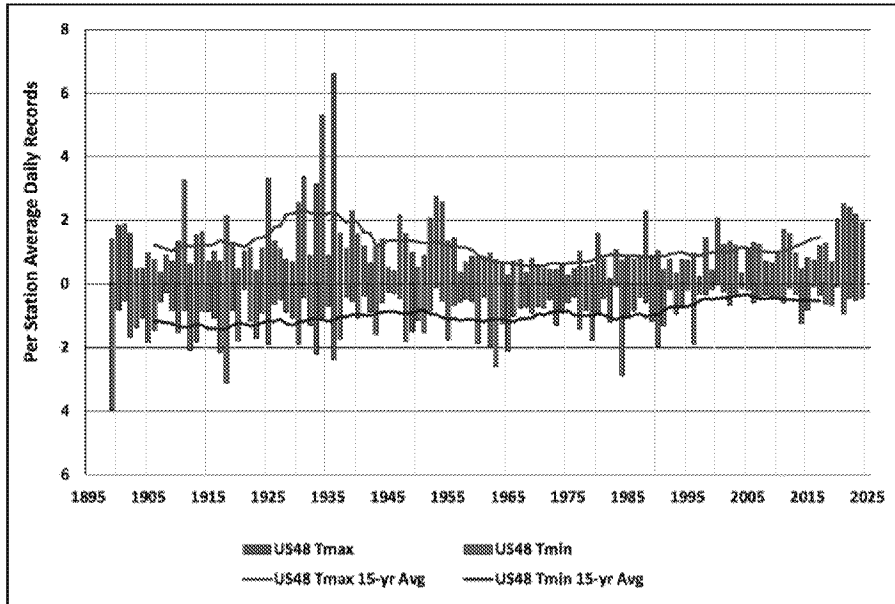


Figure ES.5: Observed changes in the occurrence of record-setting daily temperatures in the contiguous United States. Red bars indicate a year with more daily record highs than daily record lows, while blue bars indicate a year with more record lows than highs. The height of the bar indicates the ratio of record highs to lows (red) or of record lows to highs (blue). For example, a ratio of 2:1 for a blue bar means that there were twice as many record daily lows as daily record highs that year. (Figure source: NOAA/NCEI). From Figure 6.5 in Chapter 6.

The Figure appears to validate the claim that record warm daily temperatures are occurring more often. But the underlying data do not: they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as NCA4 Figure 6.4 itself later shows.

Figure ES.5 does not show what its title implies: these are not simple counts of cold and warm extreme events; instead they are ratios of the two. In fact, both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes increased. By graphing the ratio in this way the NCA4 created a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis of the data – defining each record as the singular extreme in the history, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the extreme Tmax records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio of heat to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of the NCA4 Figure ES.5.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3. **DON'T BOLD THE CAPTION**

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The National Academies' expert review panel [[HYPERLINK "https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report"](https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report)] the discussion of temperature extremes in a [[HYPERLINK "https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf"](https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf)] of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) [[HYPERLINK "https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf"](https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf)] to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The "new figure" referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies' panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn't have survived to publication. And the figure's problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

While the following statement has far less headline potential than that from the CSSR's page 19 quoted at the beginning of this box, it has advantage of being correct:

~~There have been some changes in temperature extremes across the contiguous United States. The annual number of high temperature records set shows no significant trend over the past century nor over the past 40 years, but the annual number of record cold nights has declined by a factor of 4 since 1895, somewhat more rapidly in the past 30 years.~~

END BOX

With this background we now present our critique of NCA5.

2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND NON-SCIENTIFIC TONE

NCA5 Chapter 1 “Overview” holds a prominent place in the Report since it summarizes the whole report and is the only section that many will read. Although the later Chapters of NCA5 contain much sound scholarly content, Chapter 1 is marred by a pervasive tone and language that aggressively promotes emission reduction policies. As such, this chapter adds an imprimatur of scientific authority to oversimplified declarations of opinion about public policy. Many examples can be cited; here we note a few that are particularly egregious. Here we cite a few examples that are particularly egregious.

Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that: all warming is anthropogenic in origin, all warming is bad and causes economic damage, warming causes extreme weather to intensify. Such sweeping generalizations go well beyond what science has or can establish. It also refers to growing risks without saying whether they were large to begin with: a small risk that grows may still be a small risk. A scientifically-sound version of this paragraph would instead say something like the following:

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The Earth is warming because of a combination of natural and anthropogenic influences. This warming will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. Some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases might slow the warming although such policies have proven to be costly and disruptive, so any climate actions to be weighed against the potential benefits.

On the next page the Overview goes on to say:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits...”

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms, indeed (as is acknowledged in Chapter 19 on Economics) in some cases there will be benefits. Nor is climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers.

Pages 8 and 9 promote renewable energy options by noting, correctly, that the levelized costs of wind/solar generation have fallen sharply since 2010. This is proposed as rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

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Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) can substantially increase the cost of electricity. Further, there are yet unmet synchronization challenges in transmission grids with heavy penetration of wind and solar power. Here again it is advisory malpractice not to acknowledge these facts.

Page 14 presents future emission scenarios with the following description: "Climate modeling experts develop global climate projections for a range of plausible futures." The word "plausible" is applied to all the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The figure does not contrast observed emissions against ~~model-previous~~ projections nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as "plausible" the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline "business-as-usual" future.

Page 17 introduces the discussion of risks from extreme weather events by saying "Harmful impacts from more frequent and severe extremes are increasing across the country." This creates the impression that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the value of assets at risk, ~~we could criticize Figure 1.6, which uses an anecdote to support its 1200 claim.~~

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Page 17 (and elsewhere) it then invokes the NOAA Billion Dollar Dataset as an indicator evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product. Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends and they should have taken care not to conflate extreme weather metrics with economic trends.

Page 23 states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points

not only to the willingness of NCA5 authors to promote hysteria, but also the ineffectiveness of the review process at not ensuring such statements are removed.

The tone of the Overview chapter hints at the priorities that governed the writing of the report as a whole. As a crude indicator of these priorities, word searches of the full document revealed the following occurrences:

Term	Number of occurrences
Forcing	111
Uncertainty	384
Watts	19
Culture/culturally	854
Equity/equitable	572
Indigenous	890
Sustainable	295
Racism/racial	153

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~~We won't try to cite all the remaining examples of advocacy and hyperbole in the Overview chapter; one more example will suffice. Page 26 states "Increasing flooding puts more people and assets at risk." The accompanying figure contrasts model-projected flood losses by county in 2050 to that observed in 2020 as estimated in Wing *et al.* (2022)³. Hence the evidence for the claim is not currently-observed trends, rather it is a model-generated projection of changes. But current trends in U.S.-based flooding reveal a more complex picture with a general overall trend towards less flooding. The Environmental Protection Agency's "Climate Change Indicators: River Flooding" webpage⁴ shows maps both of flood magnitude and frequency. Both show more regions experiencing declines over 1965-2015 than increases. Hence current trends indicate generally declining U.S. flood risks, but the NCA5 Overview not only fails to mention this but declares the opposite based on a single study presenting model-generated forecasts of flood activity decades in the future.~~

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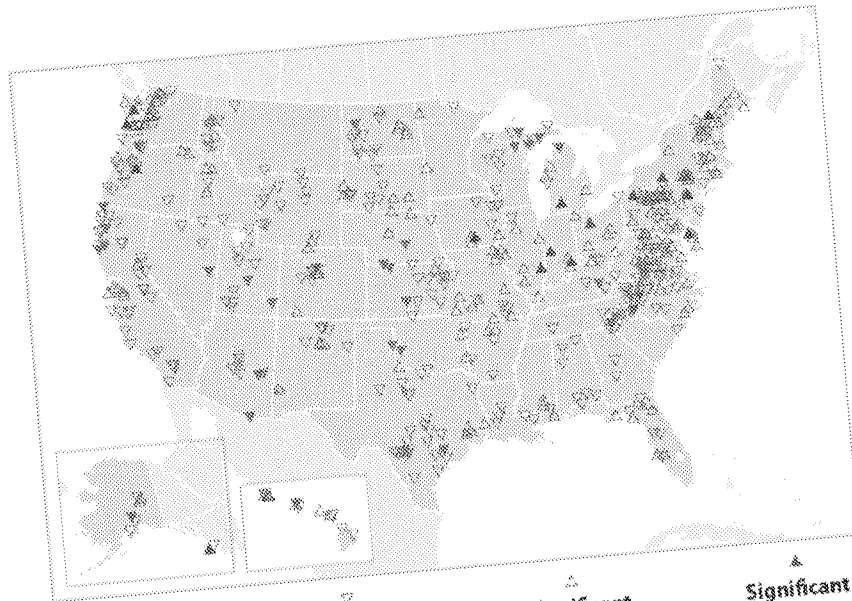
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³ Wing, Oliver, William Lehman, Paul Bates *et al.* (2022) Inequitable patterns of US flood risk in the Anthropocene. *Nature Climate Change* 12:156–162 [HYPERLINK "<https://www.nature.com/articles/s41558-021-01265-6>"]

⁴ [HYPERLINK "<https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding>"]



U.S. Flood magnitude trends 1965-2015.

Source: [HYPERLINK "<https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding/>"]

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3 ONE-SIDED OVERSIMPLIFICATIONS IN SCIENCE SUMMARY
CHAPTERS OVERCONFIDENCE WHEN STATING CONCLUSIONS

~~Chapters 2 (Climate Trends) and 3 (Earth Systems Processes) form the scientific core of NCA5. As we will show in the following examples they fail to meet statutory requirements to discuss scientific uncertainties and the role of natural variability, and they fail to meet the more stringent implicit standards expected of a policymaking policy-informing report.~~

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3.1 Inappropriate Certainty Grading ~~Inflated Certainty Levels~~

A general pattern in the NCA5 is overconfidence in stating conclusions. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

The NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of the NCA5 states that “confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.”

Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in the conclusions.

Even within the context of this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. Several illustrative examples are provided.

Key Message 3.1 Traceable Account states:

“There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.”

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Compare this statement with statements from the IPCC AR5 and AR6:

AR5: “It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together.” (IPCC, 2013)

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AR6: “The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.” (IPCC, 2021)

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The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While the NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, the AR5 refers to “*more than half* of the observed warming” and the AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

NCA5 Key message 2.2:– “Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*).”

No justification is provided in Chapter 2 for the *high confidence* conclusion on higher storm surges or hurricanes causing heavier precipitation. The Traceable Accounts section, Description of Confidence and Likelihood states:

“Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have *high confidence* that storms are delivering more rainfall and high confidence that storm surges are becoming higher.”

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In short, the NCA5 provides no observational basis or published research for their *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges; and does not meet its own standards for a *high confidence level*.

~~I WOULD DELETE THIS EXAMPLE FIRST. THE NCA5 PRETTY MUCH PARROTS WHAT THE AR6 SAID, AND LEWIS WAS PROBABLY PUBLISHED AFTER NCA5 LITERATURE CUTOFF. THE SENSITIVITY STUFF IS GOOD FOR THE CWC REPORT, BUT NOT FOR NCA ASSESSMENT.~~

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~~3.2 Increased Lower Bound of Climate Sensitivity~~

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~~The promotional tone of Chapter 1 is carried forward into Chapter 3 (Earth System Processes) where states, on page 3–10, Key Message 3.2:– states “The Estimated Range of Climate Sensitivity Has Narrowed by 50%”. Referring to Equilibrium Climate Sensitivity (ECS) the section elaborates:~~

Recent improvements in the understanding of how climate feedbacks vary across timescales have narrowed the estimated *likely* range of warming expected from a doubling of atmospheric carbon dioxide by 50% to between 4.5°F and 7.2°F (*high confidence*).... This uncertainty reduction results from advances in combining observations and targeted modeling results from nearly independent lines of evidence, each of which generally agrees on the values of ECS. The lines of evidence include 1) observed present-day variations on monthly to interannual timescales from which cloud and other climate feedbacks are inferred; 2) observed temperature changes between the preindustrial period and present and associated relationships to ERF; and 3) estimated temperature and radiative forcing changes for multiple warm and cold periods in paleoclimate records.

The graphic summary on page 3-11 states

The reduced uncertainty in climate sensitivity and climate feedback has been achieved through unprecedented quantitative synthesis of evidence from observed changes over recent decades, the industrial era, and paleoclimate.

This is a very grossly inadequate description of the situation. The key development in AR6 was a *reduction of confidence* in the ability of climate models to identify ECS and the shift away from the model-based method the IPCC had relied on since AR1 in 1990. The IPCC instead turned to data-driven ECS estimation and specifically chose a single paper from the scientific literature, Sherwood *et al.* (2020)⁵, for the purpose. It combined paleoclimate data, modern instrumental data and modern observations of climate processes, mainly cloud-related, that govern key feedbacks. Sherwood *et al.* used a subjective Bayesian method to determine the likely range of ECS values. The Bayesian approach begins with the researcher specifying a “prior”, namely an expectation of what the answer will be before seeing the data. In this case the prior consists of an expected ECS range based on the researchers’ subjective beliefs. Then the data are allowed to influence the ECS distribution and the final result is a weighted average of the assumed prior and the data-driven result. Sherwood *et al.* found a best (or median) ECS estimate of 5°F (3°C), which was close to previous model-based estimates but raised the likely lower bound by 1.7°F from 2.5°F to 4.2°F. The IPCC accepted this result and increased the best estimate to 3.1°C.

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The NCA5 was published in November 2023. Well before that, in September 2022, Lewis (2023)⁶ had been published online at *Climate Dynamics* presenting a forceful critique of Sherwood *et al.* One of Lewis’ points was that Sherwood *et al.*’s result was dependent on their chosen subjective prior. Lewis recommended using an objective Bayesian method, which places primary weight on the data rather than the researcher’s expectation. Using that and updated forcing data from AR6, Lewis estimated an ECS best estimate of 3.7°F (2.2°C) with a likely lower bound of 2.7°F (1.6°C).

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Hence, in contrast to the promotional language of Chapter 3 a more valid summary of the ECS literature as it stood at the time of writing the NCA5 would be what we wrote in CWG25 (emphasis added):

⁵Sherwood, S. C., Bony, S., Boucher, O., Bretherton, C. S., Forster, P. M., Gregory, J. M., & Stevens, B. (2020). An assessment of Earth’s climate sensitivity using multiple lines of evidence. *Reviews of Geophysics*, 58(4). [HYPERLINK “https://doi.org/10.1029/2019rg000678”]

⁶Lewis, N. (2023). Objectively combining climate sensitivity evidence. *Climate Dynamics*, 61(9–10), 3155–3163. [HYPERLINK “https://doi.org/10.1007/s00382-022-06398-8”]. The final citation for this paper is Lewis (2023) because the print edition did not appear until 2023, but the article was accepted in August 2022 and the online edition appeared and was in circulation in September 2022.

For the AR6, the IPCC placed primary weight on the results of Sherwood *et al.* (2020) that combined historical and paleoclimate proxies with the process-based approach and yielded a best estimate of 3.1°C with a *likely* range of 2.6–3.9°C. Lewis (2022) raised a number of concerns about this result, including methodological errors, outdated input values, and use of subjective versus objective Bayesian priors in the analysis. Lewis' analysis found that climate sensitivity is estimated to be much lower and better constrained than in the Sherwood *et al.* analysis—median 2.2°C (1.8–2.7°C in the 17–83 percent *likely* range, and 1.6–3.2°C in the 5–95 percent *very likely* range). **The IPCC AR6 estimated only a 5 percent probability that ECS was below 2.3°C, whereas Lewis estimated it to be over 50 percent.** The most recent publications on the debate between Sherwood *et al.* and Lewis further defend their respective positions: Sherwood and Foster (2024) and Lewis (2025).

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3.3 Presenting New Emission Scenarios as a Scientific “Advance”

Chapter 3 pp. 13–14 treats the release of new emission scenarios as a scientific “advance” without addressing the failure of many previous scenarios to match reality or providing an honest assessment of the likelihood that the new ones are remain biased in the same way.

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Key Message 3.3 states “New Data and Analysis Methods Have Advanced Climate Science” and includes the following:

New scenarios of socioeconomic development, and their associated emissions and land-use changes, drive updated climate projections from Earth system models. The Scenario Model Intercomparison Project (ScenarioMIP) organized the main set of 21st-century projection experiments under the latest phase of the Coupled Model Intercomparison Project, CMIP6. These CMIP6 projections used newly developed scenarios based on Shared Socioeconomic Pathways (SSPs; Figure 3.4). Five SSPs represent alternative plausible trajectories of 21st-century GDP and population growth and the pace and pervasiveness of socioeconomic and technological progress within individual nations and across the world (see Table 3 in the Guide to the Report). SSP-specific drivers are used in integrated assessment models (IAMs) to simulate the corresponding evolution of the energy system and the resulting greenhouse gas trajectories. These are in turn used by ESMs to drive their 21st-century projections.

There is nothing wrong with NCA5 discussing the development of new emission scenarios which serve as inputs to climate change projections and impact studies. But it is a serious omission not to inform the reader of the failure of many previous IPCC scenarios to match reality and the tendency of the scenario groups to exaggerate near-term and long-term CO₂ concentration growth (CWG25 3.2.1). It is also a serious omission not to caution readers that many climate impact studies use RCP2.5 which by the time of NCA5 had already been heavily criticized in the literature.

The same section also reports the availability of new and larger model ensembles as a scientific advance, without addressing ways in which models are getting worse in some key respects (CWG Ch 5).

~~DELETE THIS SECTION. IT IS AN OBSCURE TOPIC AND DOESN'T OBVIOUSLY FIT IN THE OVERCONFIDENCE SECTION~~

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~~3.4 Uncritical Promotion of "Emergent Constraints"~~

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Chapter 3 page 17 presents the topic of "emergent constraints" in uncritical terms:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as "emergent constraints." The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as a way to tie GCM behavior to climate observations in hopes of generating insight into real-world ECS. Climate models exhibit a wide range of sensitivities. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could check if the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a large proliferation of proposed correlations with little physical motivation. Many emergent constraints patterned on CMIP5 models failed to work on CMIP6 models (Schlund *et al.* 2020). In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the Earth climate system. The result was that emergent constraints estimated on CMIP5 models widened the range of estimated ECS values when applied to CMIP6 models.

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Schlund *et al.* summarized the problem as follows:

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In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project. The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great "advance" that reduced uncertainty.

²Schlund, Manuel, Axel Lauer, Pierre-Gentine, Steven C. Sherwood, and Veronika Syring. (2020). Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6? *Earth System Dynamics* 11: 1233-1258 [HYPERLINK "<https://doi.org/10.5194/esd-11-1233-2020>"]

~~DELETE THIS EXAMPLE, THE IMPORTANT PART OF THIS EXAMPLE IS ALREADY
IN SECTION 3.1 increasing hurricane intensity.~~

NCA5 Key message 2.2 states "Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*)."

No justification is provided in Chapter 2 for the *high confidence* conclusion on higher storm surges or hurricanes causing heavier precipitation. The Traceable Accounts section, Description of Confidence and Likelihood states: "Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes; this is why the authors also have *high confidence* that storms are delivering more rainfall and high confidence that storm surges are becoming higher." In short, the NCA5 provides no observational basis or published research for their *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges; and does not meet its own standards for a *high confidence* level.

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3.2 Overstating Findings findings in Underlying underlying Sourcesources

3.5 THIS ONE WORKS IN THE OVERCONFIDENCE CHAPTER, BUT THE EXAMPLES ARE NOT WELL DESCRIBED

Although we did not do a detailed audit of the NCA5's use of source material, a few spot checks turned up evidence of a pattern of overstatement.

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Chapter 2 page 11 reports on an increase in precipitation in central and eastern US some areas and attributes it to climate change:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

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based on a comparison of 2002-2021 average rainfall to the average over 1901-1960. Note that this a non-standard metric; we will discuss NCA5's inconsistent choices of time scales of analysis below. The change in this case is called a "trend" even though this is not how a trend is measured, and says that it is "attributable to climate change". The claims were attributed to the following paper:
~~WOULD BE BETTER TO PROVIDE A DIRECT QUOTE FROM THE NCA5~~

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- Knutson, Thomas and Fanrong Zeng (2018) "Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends" *Journal of Climate* 31(12)
[HYPERLINK "<https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml>"]

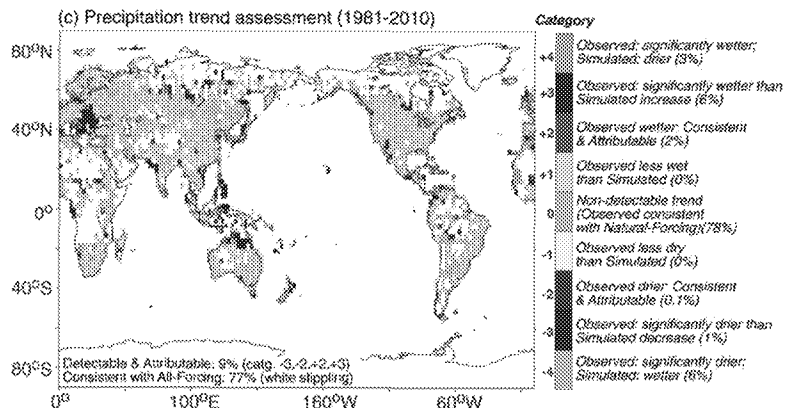
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But Knutson and Zeng did not say these things. ~~It~~ They examined linear trends over 1901 - 2010, 1951 - 2010 and 1981 - 2010. ~~It~~ They did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 - 1960, indeed ~~it~~ their study was published in 2018 so it could not have. With regard to 1981-2010 trends its results were summarized in the following figure: they noted stronger trends in some areas but cautioned that such changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States:

Observed annual precipitation trends over the recent 30-yr period 1981-2010 ([HYPERLINK "<https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml>" \l "fig5"]) have generally stronger magnitudes (in mm yr⁻¹ decade⁻¹) than observed trends for 1901-2010 or 1951-2010. This is as expected since trends over a shorter period have stronger potential for occurrence of pronounced temporary trends due to internal variability alone. Only 9% of the analyzed area has detectable and attributable anthropogenic influence (categories -3, -2, +2, +3), which represents less than one-third of the fractional areal coverage of such trends for 1901-2010 (29%). ... Eight percent of the analyzed area has attributable anthropogenic increases (categories +2, +3), including parts of eastern Europe, northern Asia, northern Australia/Maritime Continent, and tropical Africa.
~~DON'T NEED THE FIGURE, CAN YOU PROVIDE RELEVANT QUOTE FROM KNUTSON PAPER THAT IS AT ODDS WITH NCA5 CONCLUSION~~

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Gray indicates no trends detected. Stippling means that there were no trends in the models either so the models and observations agreed in that respect. Detectable and attributable trends were found over only 9% of the land surface of the Earth. Over the US there are detectable trends over only a few regions in the Southwest.

Consider a 2nd example. NCA5 Chapter 2 page 18 states

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There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is attributed to two papers:

- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. [[HYPERLINK "https://doi.org/10.1126/sciadv.aao3354"](https://doi.org/10.1126/sciadv.aao3354)]

and

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- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308-13313. [[HYPERLINK "https://doi.org/10.1073/pnas.1921628117"](https://doi.org/10.1073/pnas.1921628117)]

Diffenbaugh et al. presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not "robust" evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something which even the IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using 3 GCMs, found "A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically." However, they noted large differences among the three models in their simulated precipitation changes. Also, 2 of the 3 models failed to yield detection attribution for Rx5Day-5-day events for the North America mean, in other words the models disagreed on whether the observed changes were due to anthropogenic activity. Both cited references utilized the implausible RCP8.5 scenario and began their "historical" observational records only in 1961. Finally, the authors used Total Least Squares, an estimation method known to overstate signal detection results (CWG Section 8.3.2). Here again this is not "robust" evidence, it is suggestive but other studies have found natural variability predominant. Both cited references utilized the implausible RCP8.5 scenario and began their "historical" observational records only in 1961.

4 RELIANCE ON *Ad Hoc* TIME SCALES FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need to be careful regarding the choice of time scale when making claims about trends in extreme weather. We gave examples from analysis of river flooding (6.1), heatwaves (6.3) and extreme precipitation (6.4) to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here we elaborate on these examples to illustrate a general point that NCA5 made inconsistent and *ad hoc* choices about time scales of analysis, weakening the validity of their conclusions.

McKittrick and Christy (2019)⁸ showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017).

In CWG Section 6.4 we presented analysis of updated data for the same locations and many more besides, in all cases finding both considerable regional heterogeneity and lack of robustness of trends to use of long samples that trends detectable on one time scale are often not detected on longer or shorter time scales, which argues against simple attribution of changes to anthropogenic influences.

4.1 Average and Extreme Precipitation

Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

“Rainfall is becoming more extreme”

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion, instead it refers to changes “since the 1950s”. Fig. 2.8 suggests 1958 as the start date. For the present report we have extended the CWG25 analysis even further now to include 141 stations across the US in the Pacific Coast, Midwest, Northeast and Southeast regions. We provide details in the Appendix XX; here we note merely that once again it is possible to find trends that support the NCA5 position, but they are not robust to selecting longer or shorter time scales of analysis. Data from 1950 to 2024 yields many indications of increased average and extreme precipitation at individual stations and region-wide averages. But when using the entire data set (back to the 1890s or earlier depending on location) or the later subset (1980 to 2024) the trends become smaller, in many cases they become statistically insignificant, and occasionally they change sign. Only in the Northeast region are the post-1950 trends robust to also focusing on the post-1980 interval.

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⁸ McKittrick, R., and L.R. Christy (2019). Assessing changes in US regional precipitation on multiple time scales. *Journal of Hydrology*, 578, 124074. [HYPERLINK “https://doi.org/10.1016/j.jhydrol.2019.124074”]

The following is a more accurate summary of what U.S. data show.

There are regionally-heterogenous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution to anthropogenic warming difficult.

~~Along the Pacific coast very few stations (1 or 2 out of 29) exhibit significant trends on any time scale in any metric and the region-wide trends are insignificant. In the Southeast region about 5 out of 24 stations exhibit positive trends in average and extreme precipitation metrics and the regional trends are likewise significant, but only on samples beginning in 1950. When the sample starts in 1873 or 1980 the trends weaken and become mostly insignificant. In the Midwest region nearly half the stations exhibit positive and significant trends in average precipitation since 1893 (23/61) and 1950 (28/61) but the trends weaken after 1980; only 6/61 locations are significant and the region-wide trend is insignificant. These positive trends reflect the dryness of the 1930's Dust Bowl era. Regional trends in max and 99th percentile exceedances are insignificant post-1893 and 1980 but the latter are positive and significant post-1950.~~

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~~In the Northeast region 12 out of 27 stations exhibit positive and significant increases in average precipitation post-1888, post-1950 and post-1980 (10/27) and the regional trend is positive and significant in all three intervals. The regional number of 99th percentile exceedances has a positive trend post-1950 and post-1980 but not post-1888. The significant positive trends post-1980 are concentrated in NH but are insignificant elsewhere.~~

~~Consequently, precipitation in the U.S. exhibits considerable regional and temporal variability. Relatively more places became wetter than drier. In the Midwest and Northeast the general pattern since 1950 favors increased precipitation depending on the location, although trends since 1980 have not tended to be statistically significant.~~

~~KEEP IT FOCUSED ON THEIR MISREPRESENTATION OF EXTREME PRECIP~~

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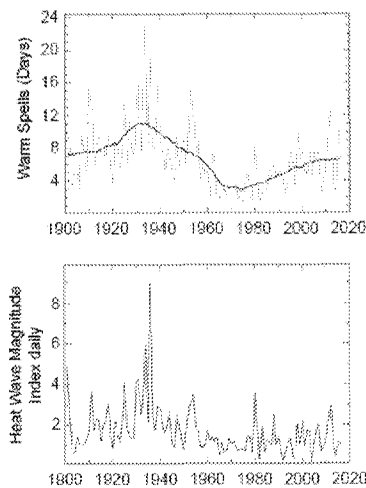
4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the whole of the 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies:

[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s.

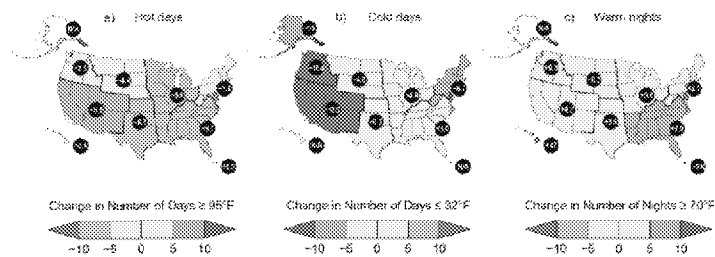
(NCA4 pp. 190-191)



U.S. Heat waves since 1900. Source: NCA4 Figure 6.4

Contrast this careful and factual language with NCA5 Key Message 2.2: “Extreme Events Are Becoming More frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 reproduced below.

Observed Changes in Hot and Cold Extremes



Hot days have increased in the West, hot nights have increased nearly everywhere, and cold days have decreased.

Figure 2.7. Over much of the country, the risk of warm nights has increased while the risk of cold days has decreased. The risk of hot days has also increased across the western US. This figure shows the observed change in the number of (a) hot days (days at or above 95°F), (b) cold days (days at or below 32°F), and (c) warm nights (nights at or above 70°F) over the period 2002–2021 relative to 1901–1960 (1951–1980 for Alaska and Hawaii and 1956–1980 for Puerto Rico). Data were not available for the US-Affiliated Pacific Islands and the US Virgin Islands. Figure credit: Project Drawdown, Washington State University Vancouver, NOAA NCBI, and CIOESS NC.

Close inspection shows that this Figure contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of the NCA4. The time scale of analysis for this Figure is stated as the number of hot days, cold days and warm nights (respectively in panels a–c) over the period 2002–2021 compared to 1901–1960. Presumably (though not stated in the caption) the counts are per year. Notwithstanding Key Message 2.2 the leftmost panel shows that over most of CONUS the number of extreme heat days has decreased in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted since it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 chapter 2 elaborates on KM2.2 by saying (p. 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But it does not mention the decline elsewhere. On the next page (p. 17) it says:

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

Reference to a global trend seems to be an attempt to tie heatwaves to climate change, but then the obvious question, unaddressed by NCA5, is why only part of the U.S. follows it while most of the country is trending in the opposite direction. These issues were addressed in CWG25 Ch6, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by natural variability than the small extra forcing from the enhanced concentrations of CO₂. The data shown in CWG25 shows that in terms of both (a) hot days ($\geq 95^\circ\text{F}$) and (b) number of days in heatwaves, the current decade is experiencing no more than was experienced 100 years ago. For example, in the 30-year period 1925–1954, representing only 23% of the 1899–2024 data record, the

CONUS experienced 33% of the total heat wave days. The most recent 30-years experienced 24%, almost exactly that expected by chance. Thus, the NCA5 claim that "multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades," is seen to be simply false when expanding the temporal and spatial domains to encompass all available data (Ch6 Fig. 6.3.6 CWG25).

The NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG Section 8.6.1 discussed this event in detail, reviewing the findings of multiple peer-reviewed studies that explained the unusual meteorological conditions giving rise to it were unrelated to climate change, a point omitted from the NCA5 discussion.

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NCA5 finally turns to the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator ([\[HYPERLINK "https://www.globalchange.gov/indicators/heat-waves"\]](https://www.globalchange.gov/indicators/heat-waves)) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed this issue in CWG25 Section 6.3. The Figure referenced by NCA5 uses an *ad hoc* definition of heat wave, namely two consecutive days with minimum nighttime temperatures above the 85th percentile, and an *ad hoc* time scale which begins in the 1960s, the coldest decade in the last century, thus suppressing any comparison to the 1930s. Nighttime temperatures in urban areas have gone up faster than daytime temperatures (which the NCA5 acknowledges), but this is a signature of urban heat island effects and is not a good metric of climate change. CWG25 noted as well that the occurrence of hot days ($\geq 95^\circ\text{F}$) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

~details: NCA4 used entire 20th century while NCA5 looked at post-1960 interval

5 INADEQUATE TRACEABLE ACCOUNTS

Starting with the NCA3, the NCA has included a section on Traceable Accounts at the end of each Chapter. ~~A-This is the~~ description from the NCA5:

"Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team's expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources."

The Traceable Accounts for each Chapter and Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts are in principle an important factor in addressing the NCA's statutory requirement to discuss scientific uncertainties. Further, the Traceable Accounts can help satisfy the Executive Order for Restoring Gold Standard Science with regards to: reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the execution of the Traceable Accounts is uneven, often superficial and noninformative in Chapters 2 and 3 (which were the only Chapters investigated here). ~~Here is An an~~ example from Chapter 2:

Key Message 2.2: Extreme Events are Becoming More Frequent and Severe.

~~The~~ Description of the Evidence Base consists of two paragraphs, with the first paragraph summarizing the findings and the second paragraph providing a generic description of the types of data that can be used for storms. Major Uncertainties and Research Gaps focuses on the uneven distribution across US populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning, and the lack of homogenized daily and hourly temperature data except from reanalysis products.

The most astonishing deficiency is in the Description of Confidence and Likelihood. One of the statements in Key Message 2.2 is:

"Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence).

"--The Description of Confidence and Likelihood includes the following statement:

"Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher."

No reference to journal publications or a specific data set is made in the Chapter regarding hurricane-induced precipitation or storm surge to support this *high confidence* conclusion.

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With regards to Chapter 3, there are some substantial inconsistencies between the Traceable Accounts for the different Key Findings:

Key Message 3-1: Human activities have caused global warming.
Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

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The Uncertainties section only addresses uncertainties in radiative forcing of greenhouse gases.

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By contrast, consider Key Message 3-4: "Humans are changing Earth System processes."

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The Traceability Analysis in this section contains arguably the most scientifically credible text in the entire Chapter. From Description of Evidence Base:

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"In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals."

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From Major Uncertainties and Research Gaps:

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"For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability."

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As part of the Traceable Account: "Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation." --Upon clicking on the eyeball icon above a particular figure, a Contact US email appears, addressed to the USGCRP. No attempt was made to send a email to elicit the Metadata information, but it is clear that this information is not readily accessible online.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.

5 ~~OVERCONFIDENCE WHEN STATING CONCLUSIONS~~

-details

6 ~~RELIANCE~~OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to “project major trends for the subsequent 25 to 100 years,” ~~the NCA relies on projections of future climate change are based on~~ estimates of future emissions ~~(the so-called SSP scenarios)~~ and/or specified levels of radiative forcing ~~(the RCP scenarios)~~. For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

~~In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.” In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. NCA5 makes the following statements observations about future the scenarios they use:~~

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“NCA5 authors were advised to assess the full range of scenarios available.” (Front Matter)

“Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency.” (Key Message 3.3 Traceable Analysis)

~~Despite acknowledging the issue The the NCA5 otherwise ignored a the problem, large body of literature (summarized in section xxx of the DOE Report) that shows the 8.5 and the 7.0 scenarios to be implausible, and advises against using them for policy making purposes. In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.”~~

Even in the context of NCA5 being advised to assess the full range of scenarios available, a keyword search of the NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, 10 figures *only* included the 8.5 scenarios: 5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13.

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The problem of relying on extreme scenarios is particularly ~~is extreme~~ acute for NCA5’s sea level rise projections. The sea level rise scenarios used in the NCA5 do not relate directly to the SSP emissions scenarios, but to specified amounts of sea level rise by 2100, whereby Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet). (Table 4 of Guide to Using this Report).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5

Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 50 years (2020–2069), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2013.¹¹

Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

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Considering only projections representing processes in whose quantification there is quantified with at least medium confidence, the IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m for the (5th—95th percentile range), for all scenarios ranging from RCP2.6 to RCP8.5. The IPCC AR6 cites values as high as 2.4 m at the upper end of the 95th percentile range for RCP8.5, if estimates include the hypothesized Marine Ice Cliff Instability (low confidence). The corresponding

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Nevertheless, the range of sea level rise scenarios considered by the NCA5 includes Intermediate-High (1.5 m) and High (extends to 2.0 m) values that associated with the implausible extreme emissions scenario RCP8.5 and processes in which there is low confidence in understanding. Further, the NCA5 neglects to include plausible lower scenarios, such as 0.2 m cited by the IPCC, that which also corresponds to the average rate of sea level rise over the past century.

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With regards to actual predictions of sea level rise, Chapter 9 of the NCA states: "Under a range of potential global warming levels, average sea level along US coastlines is likely to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2)." These values of sea level rise encompass the Intermediate scenario to values slightly higher than the High scenario from NCA5 Table 4 shown above. << which Table 4?

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Global sea level rise projections to 2050 relative to a 2000 baseline can be evaluated with respect to the observed global sea level rise from 2000–2024, which is approximately 3.39 inches (0.28 feet). [HYPERLINK "https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level"]

Hence it is inferred that NCA5 is projecting values of sea level rise between 2025 and 2050 that are 3.5 to 5.8 times the rate observed during 2000–2024.

Chapter 9 further states: “Looking toward the future, an 11 inch [28 cm] average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches.” This analysis accounts for the observed sea level rise between 2000 and 2020.

With regards to confidence levels, NCA5 Chapter 9 Traceable Accounts states: “There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050” Neither the statement nor the context in the paragraph does not distinguish as to whether this refers to global sea level rise, or US average sea level rise, although it is inferred to refer to global sea level rise.

In summary, the NCA5 presents future sea level rise scenarios that are not directly relatable either to SSP/RCP emissions scenarios or global Global warming Warming levels Levels. The NCA5 scenarios include some two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and that include hypothesized ice sheet processes for which there is low confidence. Projections to 2050 require rates of sea level rise during from 2025 through to 2050 that are more than three times the rate observed during 2020-2024. Further, the NCA5 ascribes *high confidence* to these sea level rise projections.

The In summary, the NCA5 inclusion, and even the focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

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7 BIASED SELECTION OF REFERENCES

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8 SUMMARY: EVALUATING ~~EVALUATION~~ OF THE NCA5

8.1 Inadequate NASEM Review

The NASEM Review failed to raise any of these ~~the~~ issues ~~we have discussed herein~~. Much of it focused on social and policy issues (e.g., Comments on Equity and Justice), rather than on the underlying science. In our assessment NASEM failed to apply the serious rigor one would expect. A few extracted comments from it will illustrate. Note that NASEM review comments are included here in blue font for reference. NASEM praised ~~the section Chapter 2 as a whole by~~, saying:

The chapter [2] meets the requirements of Section 106 of the GCRA.

Yet contrary to the requirements of Section 106 the NCA5 did not discuss natural variability let alone assess the full climate record available for quantifying natural variability. Chapter 2 actually minimizes natural variability by claiming (unsubstantiated) skill in attributing recent extremes to human causes. For example NCA5's Chapter 2 Introduction states,

"...recent advances in attribution science (KM [[HYPERLINK "https://nca2023.globalchange.gov/chapter/3"](https://nca2023.globalchange.gov/chapter/3) \l "key-message-3" \t "_blank"]) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."

CWG25 reviews the expert literature demonstrating that this particular event would have happened with or without climate change and that for the CONUS, hot extremes are no more frequent now than they were in the past. NASEM did not challenge the unsubstantiated attribution claims in the NCA5.

Notwithstanding NASEM's claim that ~~the section Chapter~~ complies with Section 106 of the GCRA it then acknowledged the absence of discussion of natural variability:

...the discussion and references regarding the role of natural climate variability and its regional differences are missing.

While a nod to natural variability is occasionally found in NCA5, it is usually followed by a "however" to emphasize human influence. One example is the statement just before the claim mentioned above pertaining to extreme event attribution: "There has always been extreme weather, which occurs even in an unchanged climate due to the natural variability of the Earth system. However, recent advances in attribution science (KM [[HYPERLINK "https://nca2023.globalchange.gov/chapter/3"](https://nca2023.globalchange.gov/chapter/3) \l "key-message-3" \t "_blank"]) mean that the role of climate change in some extreme events can now be quantified in real time..."

We pointed out that the evidence regarding heatwaves directly contradicts Key Message 2.2. NASEM did not mention this, instead it focused on a somewhat esoteric issue of terminology:

"Extreme Events Are Becoming More Frequent and Severe."

Key Message 2.2 is another generally well written key message. However, while the title of this key message includes the word "risk," the key message is exclusively about hazard. The Committee suggests rewriting the key message title to more accurately reflect the discussion on hazards.

The NASEM review appears to accept the NCA5's use of short data records because it makes no critical remarks about the failure to assess long time series, except for its observation that the use of short records makes the omission of natural variability that much more of a problem:

It is also important to point out that the influence of natural climate variability becomes particularly strong when the climate trend is computed based on short periods of time or small geographic areas.

This comment was largely ignored in the NCA5 final text.

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8.18.2 Pertinent aspects when evaluating NCA5 in light of statutory requirements

- not our remit to make a ruling but here are aspects to consider in light of statutory requirements

8.28.3 Evaluation from the perspective of expert users of the report

- we have deep knowledge of the topics surveyed by the NCA5 authors
- we do not have confidence that the report was balanced and comprehensive
- we can point to many specific instances in which the report did not exhibit an appropriate level of quality or integrity as a scientific document
- we have reason to believe the whole process, from author selection to handling of expert reviews, was biased towards reinforcing foregone conclusions and alarmist messaging

8.38.4 Evaluation from the perspective of citizens interested in good policymaking

- Public concerns about climate change are valid, as are concerns about cost of living, economic growth, employment, etc.
- We share the general concern that elected officials and those who serve them have the best information available when making important decisions around energy and climate policy
- NCA5 was a missed opportunity: it could have been a valuable input to that process but it did not turn out that way
- consequently its usage is unlikely to lead to better decisions and would more likely increase the error rate in policy formation and we recommend it not be used for policymaking purposes.

APPENDIXES

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APPENDIX 1: Seth's letter on statutory requirements for NCA5

APPENDIX 2: Analysis of 141 U.S. Longterm Daily Precipitation Records.

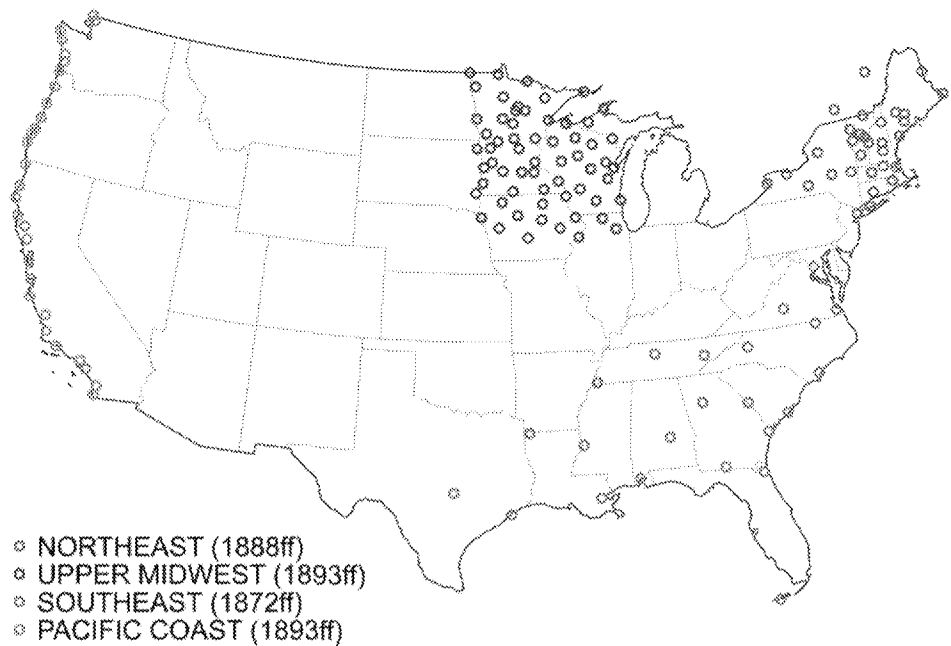


Figure. Stations used in the following analyses.

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure
Column 2: Number of stations in that region
Column 3: Count of stations exhibiting a significant positive trend
Column 3: Count of stations exhibiting a significant negative trend
Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)

Number of 99 th pct exceedances	29	1	0	(-)
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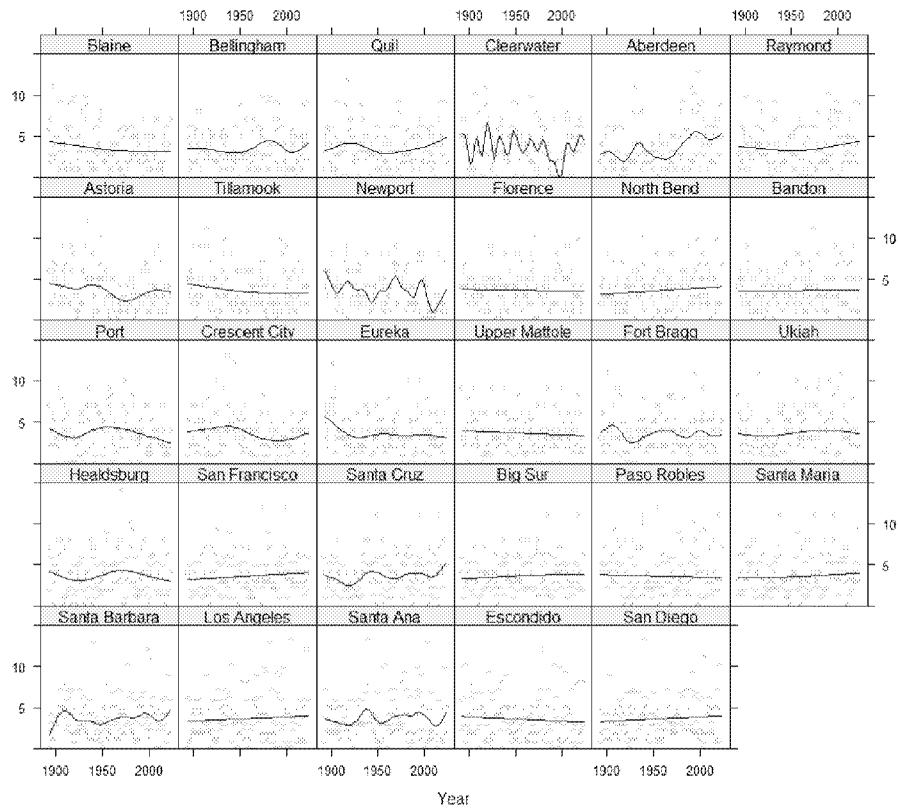
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

Annual No. 99th Percentile Exceedances PC 1893-2024



SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

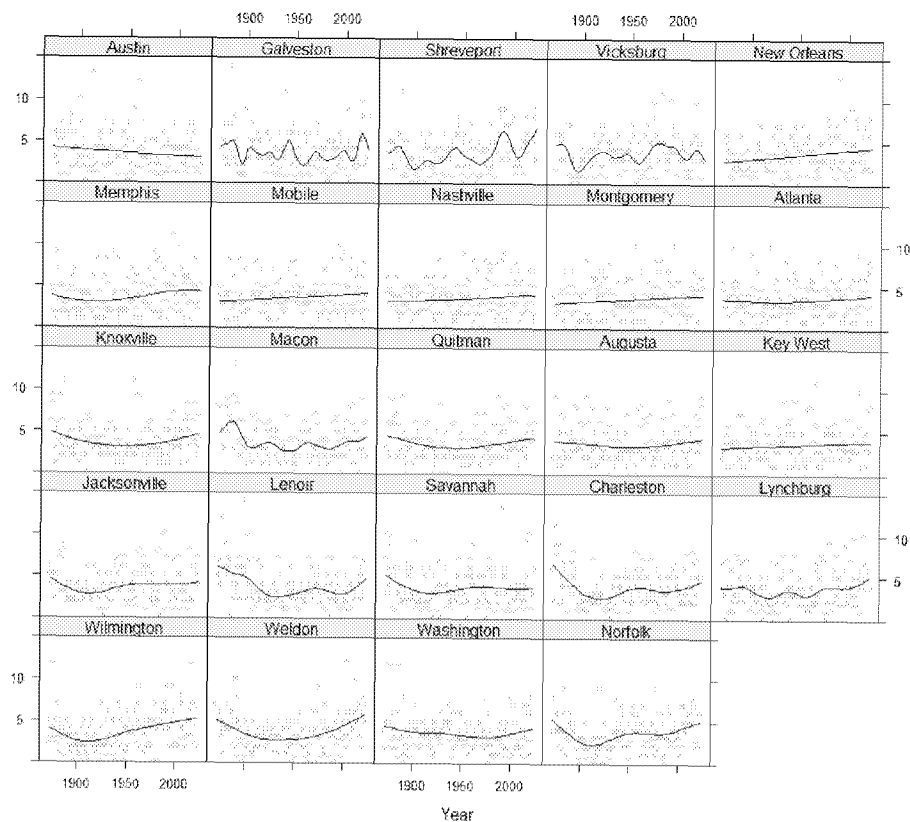
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

Annual No. 99th Percentile Exceedances SE 1873-2024



MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

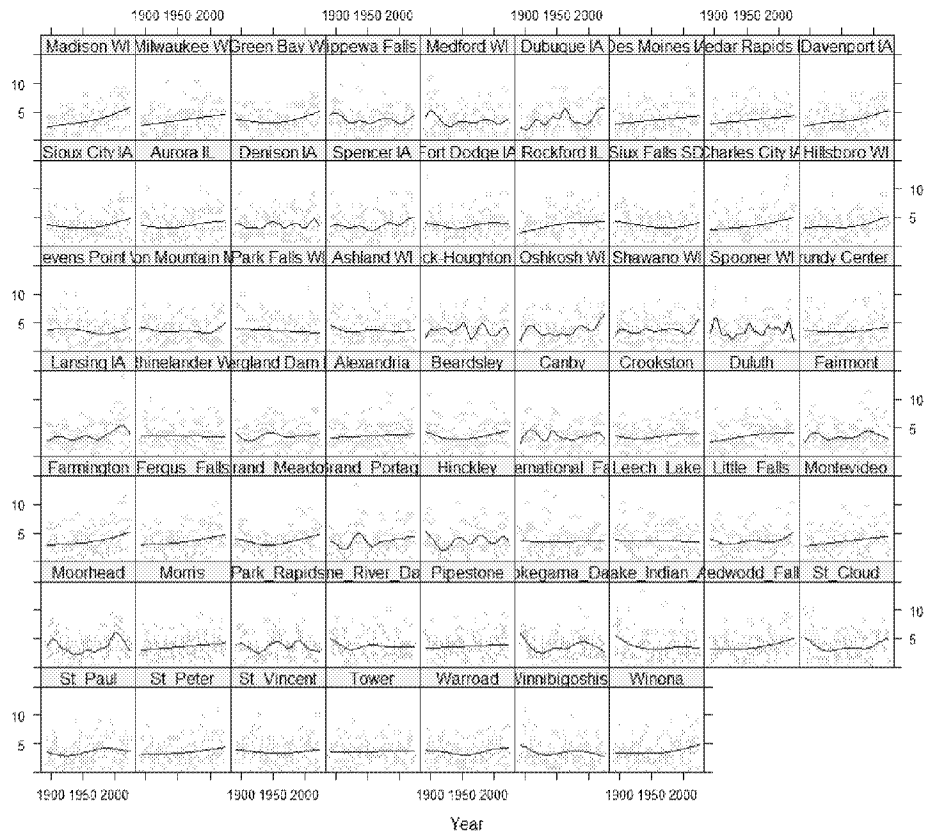
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

Annual No. 99th Percentile Exceedances MW 1893-2024



NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

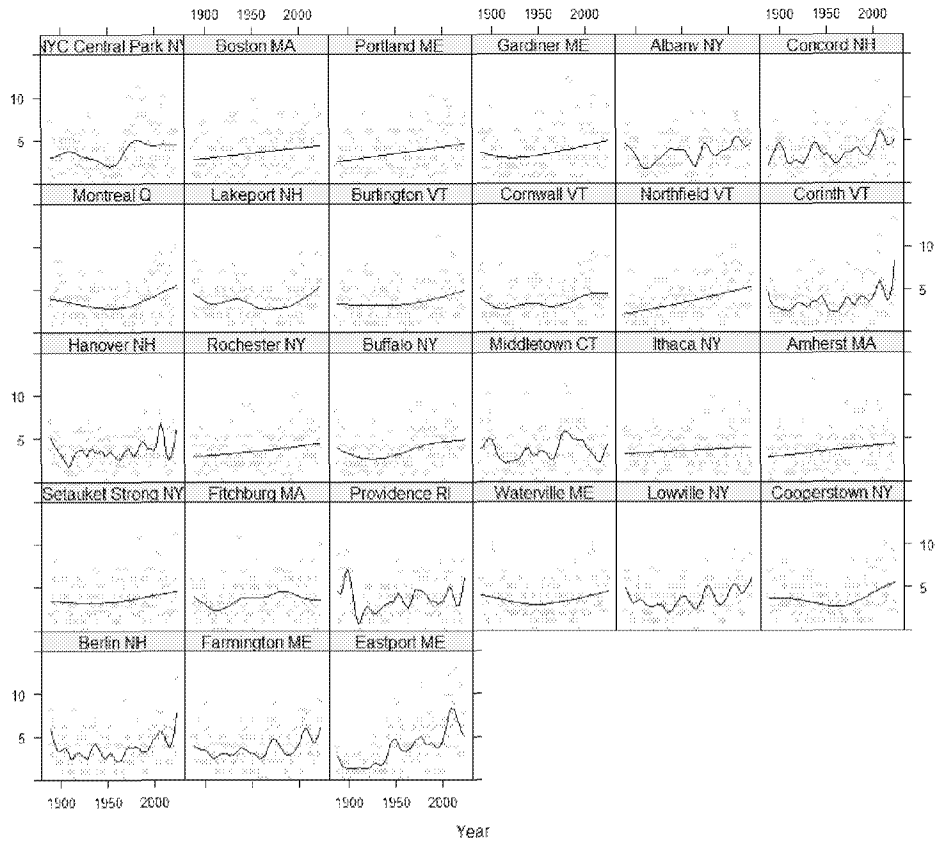
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

Annual No. 99th Percentile Exceedances NE 1888-2024



Review of the Fifth National Climate Assessment

[TOC \O "1-3" \H \Z \U]

1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix 1) that we assess the suitability of the [[HYPERLINK "https://nca2023.globalchange.gov/"](https://nca2023.globalchange.gov/)] for informing climate and energy policies.

To conduct our assessment, we reviewed NCA5 itself, the NASEM review of the Third Order Draft and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, IPCC and other organizations, as writers, reviewers and study leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science as of its publication date in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted "CWG25"). The overall effect of NCA5's biases and omissions is an excessively dire picture of climate risk.

Our report begins with background on the National Climate Assessments. We then discuss the standards by which we have assessed NCA5, followed by specific deficiencies that we have identified.

1.2 About the National Climate Assessments

The [[HYPERLINK "https://www.globalchange.gov/"](https://www.globalchange.gov/)] (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.

- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences.
- NCA4 (2017/2018) was an expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science. NCA4 introduced a traceability analysis for each key finding, including a cursory description of uncertainties.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on "Climate Action" and policy recommendations with a social justice emphasis. NCA5's self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA's statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (see Section 1.4 below). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

In Appendix 2 we include a letter of guidance from the Office of General Counsel, U.S. Department of Energy, summarizing the extent of statutory requirements governing USGCRP work products in general and NCA products in particular.

We can summarize the standards applicable to the NCA as follows:
- details.

Beyond the statutory requirements we draw attention to two other pertinent standards. President Trump's executive order of May 23, 2025, "[[HYPERLINK "https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/"](https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/)]" enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some have found them [[HYPERLINK "https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science"](https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science)].

There are other desiderata for scientific reports that will be highly influential on climate policymaking. Among them are statements about the strength of climate knowledge. The IPCC's approach is based on judgment of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include: REFERENCE AVEN

- The degree to which the assumptions made are reasonable/realistic based on background knowledge—concern about the focus on implausible emissions scenarios RCP8.5/SSP5–8.5
- The degree to which data/information exists and are reliable and relevant—the historical and paleo database is inadequate for a complete characterization of natural climate variability on multi-decadal to millennial time scales
- The degree to which there is disagreement among experts (including those from different environments or academic fields)—attempts to suppress disagreement and alternative perspectives among experts
- The degree to which the phenomena involved are understood and accurate models exist—concerns about the fidelity and utility of climate models
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns and—neglect of the unknown knowns associated with natural climate variability

Commented [A1]: Terje Aven, "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices," *Reliability Engineering & System Safety* 167 (November 2017): 42–48

[[HYPERLINK "https://www.sciencedirect.com/science/article/pii/S0951832016306950"](https://www.sciencedirect.com/science/article/pii/S0951832016306950)]

Good climate and energy policies will balance the risks and benefits of a changing climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a unique responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.

Because climate is at the core of human existence, it can engender passion and emotion. Indeed, some younger climate scientists have gone into the field to "save the planet." So it isn't surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem in a 1980 [[HYPERLINK "https://science.sciencemag.org/content/208/4448/1093"](https://science.sciencemag.org/content/208/4448/1093)] that resonates eerily four decades later:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically

scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

1.4 When Peer-Review Fails: An Example from NCA4

The peer-review of reports from the IPCC USGCRP is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, NCA reviewers self-select on a volunteer basis whether to provide comments and what parts of the report to read, whereas the editors of academic journals recruit reviewers and assign them to specific papers. There is no guarantee that any particular section of an NCA report was reviewed by anyone, let alone by someone with a different perspective than the authors. This is a problem with NCA and IPCC reports since over the years many potential reviewers have given up making the effort, because their input has systematically been ignored. Second, NCA authors have near complete authority whether to accept or reject review comments. Here, for example, is how a review comment critical of a section of the NCA5 draft was handled by the authors:

REVIEWER COMMENT

Tropical Cyclones/hurricanes have not increased (Klotzbach, P.J., Bowen, S.G., Pielke, R. and Bell, M., 2018. Continental US hurricane landfall frequency and associated damage: Observations and future risks. Bulletin of the American Meteorological Society, 99(7), pp.1359-1376., Pielke, R., 2021. Economic Normalisation of disaster losses 1998-2020: A literature review and assessment. Environmental Hazards, 20(2), pp.93-111.)

US NCA RESPONSE

Thank you for your comment.

This comment is inconsistent with the author team's thorough assessment of the science.

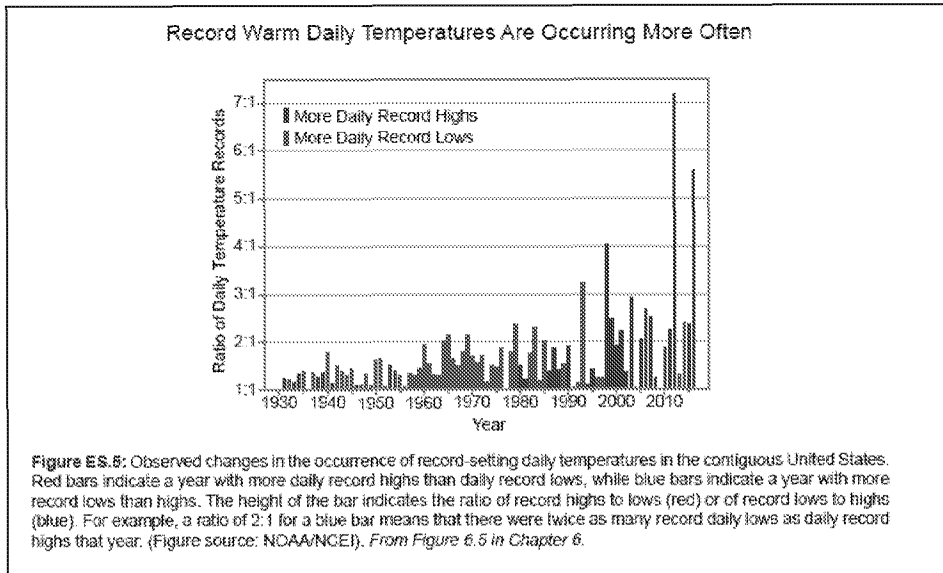
By contrast, the editor of an academic journal mandates the authors' response and the reviewer gets to assess its adequacy. And third, the work of an NCA chapter author team is guaranteed to be published, whereas academic journals routinely reject papers that do not pass review.

These points are important because some readers might dismiss any criticism of NCA products out of hand on the grounds that the reports were "peer reviewed". But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

As shown in CWG25 Section 6.3, the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Taking cold and hot extremes together the U.S. climate has become more moderate over time. Yet NCA4's Part I ([[HYPERLINK "https://science2017.globalchange.gov/"](https://science2017.globalchange.gov/)], CCSR) says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

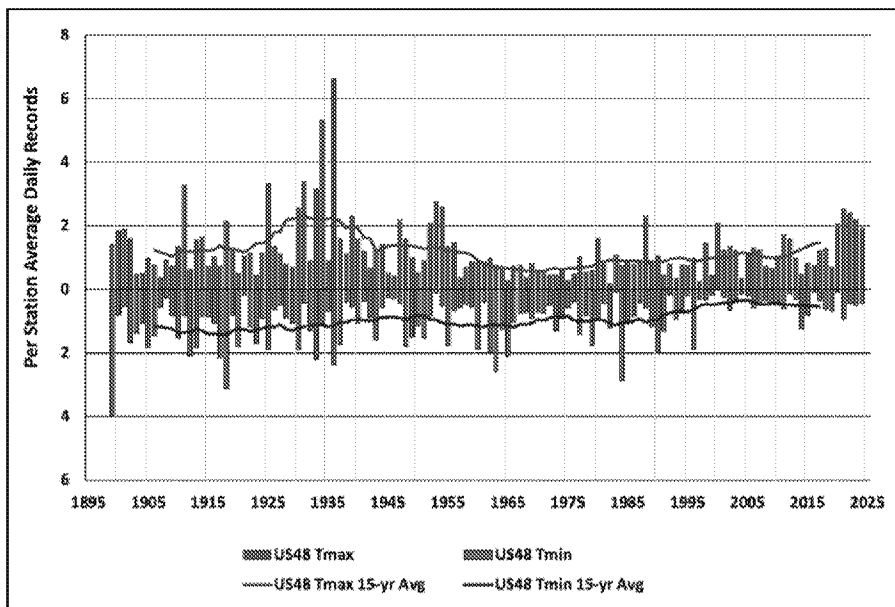
and offers this figure in support:



The figure appears to validate the claim that, as its title says, record warm daily temperatures are occurring more often. But the underlying data do not: rather, they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as NCA4 Figure 6.4 in the report itself shows.

In fact, Figure ES.5 does not even show what its title implies. These are not simple counts of cold and warm extreme events, but rather they are ratios of the two counts. In fact, both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes goes up. By graphing the ratio instead of counts, NCA4 created a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis – defining each record as the singular extreme in the history, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the extreme heat records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio shown in the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of the NCA4 Figure.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3.

The National Academies' expert review panel [[HYPERLINK "https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report"](https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report)] the discussion of temperature extremes in a [[HYPERLINK "https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf"](https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf)] of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) [[HYPERLINK "https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf"](https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf)] to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The “new figure” referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies’ panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn’t have survived to publication. And the figure’s problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

With this background we now present our critique of NCA5.

2 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

The opening Chapter 1 “Overview” is critical to NCA5 since it summarizes the whole report and is the only section that many will read. Although the later chapters of NCA5 contain much sound scholarly content, Chapter 1 is marred by a pervasive tone and language aggressively promoting emission reduction policies. The authors must have known this chapter would be mined for quotes by the media and activists looking to add an imprimatur of scientific authority to oversimplified declarations of opinion. Many examples can be cited; here we note a few that are particularly egregious.

Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes all warming is anthropogenic, all warming is bad and causes economic damage, and warming causes extreme weather to intensify. Further, there is no quantification – even if risks increase, how big are they? Such sweeping generalizations go well beyond what science has or can establish. A scientifically-sound version of this paragraph would instead say something like the following:

The Earth is warming because of a combination of natural and anthropogenic influences. This warming will generate a mix of benefits and harms that varies by region and to which society should be prepared to adapt. Some types of extreme weather have worsened recently while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases might slow the warming although such policies have proven to be costly and disruptive, so any climate actions should be weighed against the potential benefits.

On the next page the Overview goes on to say:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy] ... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits...”

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms, indeed (as is acknowledged in NCA5 Chapter 19 on Economics) in some cases

there will be benefits. Nor is climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers.

NCA5 Page 1-9 promotes renewable energy options by noting, correctly, that the levelized costs of wind/solar generation have fallen sharply since 2010. Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through gas, fission, or storage) more than doubles the cost of electricity. Further, there are yet-unmet synchronization challenges in wind/solar-heavy grids. Here again it is advisory malpractice not to acknowledge these facts.]

Page 1-14 presents future emission scenarios with the following description: "Climate modeling experts develop global climate projections for a range of plausible futures." The word "plausible" is applied to all the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The figure does not contrast observed emissions against previous projections, nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst-case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as "plausible" the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline "business-as-usual" future.

[We could criticize Figure 1.6, which uses an anecdote to support its 1200 claim.]

Page 1-17 (and elsewhere) invokes the NOAA Billion Dollar Dataset as an indicator of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) [since it measures the growth of the economy not the frequency of extreme weather] and indeed NOAA has withdrawn the data product. Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends.

Page 1-23 states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote hysteria, but also the ineffectiveness of the review process in removing such statements.

We won't try to cite all the remaining examples of advocacy and hyperbole in the Overview chapter; one more example will suffice. Page 1-26 states "Increasing flooding puts more people and assets at risk." The accompanying figure contrasts model-projected flood losses by county in 2050 to that observed in 2020 as estimated in Wing *et al.* (2022)¹. The evidence for the claim is thus not observed trends, but rather a model-generated projection of changes. Current trends in U.S.-based flooding reveal a more complex picture with a general overall trend towards less flooding. The Environmental

Commented [SK2]: Perhaps we should cite the relevant text from NCA5 Box 1.1 (pg 1-8):

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources (Figures 1.2, 1.3), (5.3, 12.3, 32.1, 32.2; Figure A4.17)

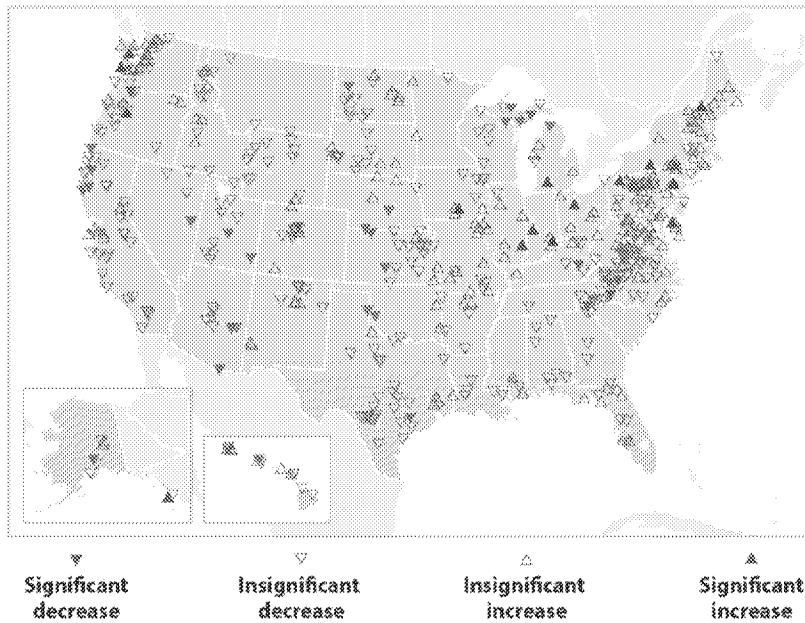
Commented [SK3]: Didn't AR6 WG1 deem 7.0 and 8.5 scenarios "low likelihood"?

Commented [SK4]: They actually say this sort of, on pg 1-17, but don't make the effort to untangle hazard vs risk, and go on to blame it all on climate change

Commented [SK5]: Some climate changes are benign or even beneficial

¹ Wing, Oliver, William Lehman, Paul Bates *et al.* (2022) Inequitable patterns of US flood risk in the Anthropocene. *Nature Climate Change* 12 156—162 [HYPERLINK "<https://www.nature.com/articles/s41558-021-01265-6>"]

Protection Agency's "Climate Change Indicators: River Flooding" webpage² shows maps both of flood magnitude and frequency. Both show more regions experiencing declines over 1965-2015 than increases. Hence current trends indicate generally declining U.S. flood risks, but the NCA5 Overview not only fails to mention this but declares the opposite based on a single study presenting model-generated forecasts of flood activity decades in the future.



U.S. Flood magnitude trends 1965-2015.

Source: [[HYPERLINK "https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding"](https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding)]

² [[HYPERLINK "https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding"](https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding)]

3 OVERCONFIDENCE WHEN STATING CONCLUSIONS

3.1 Inflated certainty levels

Overconfidence in stating conclusions is an endemic problem in NCA5. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated certainty levels.

The NCA5 uses specific terms to convey information about scientific confidence associated with important findings, observations, and projections. The Front Matter of the NCA5 states that “confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.” Its Table 1 provides calibrated language for confidence assessment:

- **Very high:** Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
- **High:** Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
- **Medium:** Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
- **Low:** Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: high *confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. Here are two examples:

Key Message 3.1 Traceable Account states:

“There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.”

While the corresponding statements from the IPCC AR5 and AR6 are:

AR5: “It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together.” (IPCC, 2013)

AR6: “The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed

GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by – 0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.” (IPCC, 2021)

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While the NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, the AR5 refers to “*more than half* of the observed warming” and the AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

As the second example, NCA5 Key message 2.2 reads:

“Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*).”

No justification is provided in Chapter 2 for the *high confidence* conclusion about higher storm surges or hurricanes causing heavier precipitation. The Traceable Accounts section, Description of Confidence and Likelihood states:

“Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have *high confidence* that storms are delivering more rainfall and high confidence that storm surges are becoming higher.”

In short, NCA5 provides no observational basis or published research for their *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges, thus failing meet its own standards for a *high confidence* level.

3.2 Range of climate sensitivity

Chapter 3 (Earth System Processes) states, on page 3-10, Key Message 3.2: “The Estimated Range of Climate Sensitivity Has Narrowed by 50%”. Referring to Equilibrium Climate Sensitivity (ECS) the section elaborates:

Recent improvements in the understanding of how climate feedbacks vary across timescales have narrowed the estimated *likely* range of warming expected from a doubling of atmospheric carbon dioxide by 50% to between 4.5°F and 7.2°F (*high confidence*).... This uncertainty reduction results from advances in combining observations and targeted modeling results from nearly independent lines of evidence, each of which generally agrees on the values of ECS. The lines of evidence include 1) observed present-day variations on monthly to interannual timescales from which cloud and other climate feedbacks are inferred; 2) observed temperature changes between the preindustrial period and present and associated relationships to ERF; and 3) estimated temperature and radiative forcing changes for multiple warm and cold periods in paleoclimate records.

The graphic summary on page 3-11 states

The reduced uncertainty in climate sensitivity and climate feedback has been achieved through unprecedented quantitative synthesis of evidence from observed changes over recent decades, the industrial era, and paleoclimate.

This is a grossly inadequate description of the situation. The key development in AR6 was a *reduction* of confidence in the ability of climate models to identify ECS and the shift away from the model-based method the IPCC had relied on since AR1 in 1990. The IPCC instead turned to data-driven ECS estimation and specifically chose a single paper from the scientific literature, Sherwood *et al.* (2020³) for the purpose. It combined paleoclimate data, modern instrumental data and modern observations of climate processes, mainly cloud-related, that govern key feedbacks. Sherwood *et al.* used a subjective Bayesian method to determine the likely range of ECS values. The Bayesian approach begins with the researcher specifying a “prior”, an expectation of the likely distribution of answers before seeing the data. In this case the prior is an expected ECS range based on the researchers’ subjective beliefs. The data are then allowed to influence the ECS distribution, and the final result is a weighted average of the assumed prior and the data-driven result. Sherwood *et al.* found a best (or median) ECS estimate of 5.4°F (3°C), which was close to previous model-based estimates but raised the likely lower bound by 1.7°F from 2.5°F to 4.2°F. The IPCC accepted this result and increased the best estimate to 3.1°C.

The NCA5 was published in November 2023. Well before that, in September 2022, Lewis (2023) had been published online at *Climate Dynamics* presenting a forceful critique of Sherwood *et al.*⁴ One of Lewis’ points was that Sherwood *et al.*’s result was dependent on their chosen subjective prior. Lewis recommended using an objective Bayesian method, which places primary weight on the data rather than the researcher’s expectation. Using that method and updated forcing data from AR6, Lewis estimated an ECS best estimate of 4.0°F (2.2°C) with a likely lower bound of 2.9°F (1.6°C).

Hence, in contrast to the promotional language of Chapter 3 a more valid summary of the ECS literature as it stood at the time of writing the NCA5 would be what we wrote in CWG25 (emphasis added):

For the AR6, the IPCC placed primary weight on the results of Sherwood *et al.* (2020) that combined historical and paleoclimate proxies with the process-based approach and yielded a best estimate of 3.1°C with a *likely* range of 2.6-3.9°C. Lewis (2022) raised a number of concerns about this result, including methodological errors, outdated input values, and use of subjective versus objective Bayesian priors in the analysis. Lewis’ analysis found that climate sensitivity is estimated to be much lower and better constrained than in the Sherwood *et al.* analysis – median 2.2°C (1.8–2.7°C in the 17–83 percent *likely* range, and 1.6–3.2°C in the 5–95 percent *very likely* range). **The IPCC AR6 estimated only a 5 percent probability that ECS was below 2.3°C, whereas Lewis estimated it to be over 50 percent.** The most recent publications on the debate between Sherwood *et al.* and Lewis further defend their respective positions: Sherwood and Foster (2024) and Lewis (2025).

3.3 New emission scenarios as a scientific “advance”

³ Sherwood, S. C., Bony, S., Boucher, O., Bretherton, C. S., Forster, P. M., Gregory, J. M., & Stevens, B. (2020). An assessment of Earth’s climate sensitivity using multiple lines of evidence. *Reviews of Geophysics*, 58(4). [HYPERLINK “<https://doi.org/10.1029/2019rg000678>”]

⁴ Lewis, N. (2023). Objectively combining climate sensitivity evidence. *Climate Dynamics*, 61(9–10), 3155–3163. [HYPERLINK “<https://doi.org/10.1007/s00382-022-06398-8>”]. The final citation for this paper is Lewis (2023) because the print edition did not appear until 2023, but the article was accepted in August 2022 and the online edition appeared and was in circulation in September 2022.

Chapter 3 pages 13-14 treats the release of new emission scenarios as a scientific “advance” without addressing the failure of many previous scenarios to match reality or providing an honest assessment of the likelihood that the new ones remain biased in the same way.

Key Message 3.3 states “New Data and Analysis Methods Have Advanced Climate Science” and includes the following:

New scenarios of socioeconomic development, and their associated emissions and land-use changes, drive updated climate projections from Earth system models. The Scenario Model Intercomparison Project (ScenarioMIP) organized the main set of 21st-century projection experiments under the latest phase of the Coupled Model Intercomparison Project, CMIP6. These CMIP6 projections used newly developed scenarios based on Shared Socioeconomic Pathways (SSPs; Figure 3.4). Five SSPs represent alternative plausible trajectories of 21st-century GDP and population growth and the pace and pervasiveness of socioeconomic and technological progress within individual nations and across the world (see Table 3 in the Guide to the Report). SSP-specific drivers are used in integrated assessment models (IAMs) to simulate the corresponding evolution of the energy system and the resulting greenhouse gas trajectories. These are in turn used by ESMS to drive their 21st-century projections.

There is nothing wrong with NCA5 discussing the development of new emission scenarios which serve as inputs to climate change projections and impact studies. But it is a serious omission not to inform the reader of the failure of many previous IPCC scenarios to match reality and the tendency of the scenario groups to exaggerate near-term and long-term growth of CO₂ concentration (CWG25 3.2.1). It is also a serious omission not to caution readers that many climate impact studies use RCP8.5 which had already been heavily criticized in the literature by the time of NCA5.

The same section also reports the availability of new and larger model ensembles as a scientific advance, without addressing ways in which models are getting worse in some key respects (CWG Ch 5).

3.4 “Emergent Constraints” and uncertainty in climate projections

Chapter 3 page 17 presents the topic of “emergent constraints” in uncritical terms:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as “emergent constraints.” The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie GCM behavior to climate observations in hopes of generating insight into real-world ECS. Climate models exhibit a wide range of sensitivities. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could check if the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a large proliferation of proposed correlations with little physical motivation. Many emergent constraints patterned on CMIP5 models failed to work on CMIP6 models (Schlund *et al.* 2020)⁵. In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the Earth climate system. The result was that emergent constraints estimated on CMIP5 models widened the range of estimated ECS values when applied to CMIP6 models.

Schlund *et al.* summarized the problem as follows:

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great “advance” that reduced uncertainty.

3.5 Overstating findings in underlying sources

Although we did not do a detailed audit of the NCA5’s use of source material, a few spot checks turned up evidence of a pattern of overstatement.

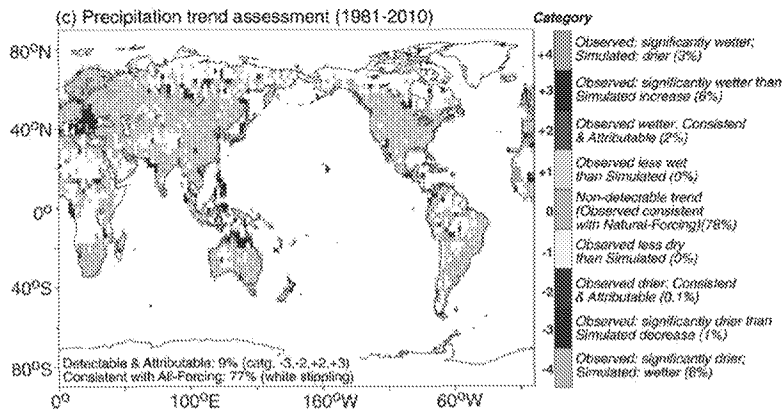
Chapter 2 page 2-11 reports on an increase in precipitation in central and eastern US based on a comparison of 2002-2021 average rainfall to the average over 1901-1960. Note that this a non-standard metric; we will discuss NCA5’s inconsistent choices of time scales of analysis below. The change in this case is called a “trend” even though this is not how a trend is measured, and says that it is “attributable to climate change”.⁶ The claims were attributed to the following paper:

- Knutson, Thomas and Fanrong Zeng (2018) “Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends” *Journal of Climate* 31(12) [HYPERLINK "<https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml>"]

⁵ Schlund, Manuel, Axel Lauer, Pierre Gentine, Steven C. Sherwood, and Veronika Eyring (2020) Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6? *Earth System Dynamics* 11 1233-1258 [HYPERLINK "<https://doi.org/10.5194/esd-11-1233-2020>"]

⁶ This statement of attribution is misleadingly ambiguous. Because NCA5’s Glossary defines “climate change” as a change in climate for any reason, the statement is a tautology and hence superfluous. But because the popular perception of climate change is anthropogenic, its gratuitous inclusion effectively attributes the change to greenhouse gas emissions.

But Knutson and Zeng did not say these things. It examined linear trends over 1901 – 2010, 1951 – 2010 and 1981 – 2010. It did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 – 1960, indeed it was published in 2018 so it could not have. Its results for 1981-2010 trends were summarized in the following figure:



Gray indicates no trends detected. Stippling means that there were no trends in the models either so the models and observations agreed in that respect. Detectable and attributable trends were found over only 9% of the land surface of the Earth. Over the US there are detectable trends over only a few regions in the Southwest.

As another example of overstating findings, NCA5's Chapter 2 page 2-18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is allegedly supported by two papers:

- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. [[HYPERLINK "https://doi.org/10.1126/sciadv.aao3354"](https://doi.org/10.1126/sciadv.aao3354)]

and

- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308-13313. [[HYPERLINK "https://doi.org/10.1073/pnas.1921628117"](https://doi.org/10.1073/pnas.1921628117)]

Diffenbaugh et al. presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S.

extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not “robust” evidence of anthropogenic influence since it rests on the assumption that climate models provide accurate simulations of regional precipitation patterns, something that even the IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using 3 GCMs, found

“A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically.”

However, they noted large differences among the three models in their simulated precipitation changes. Also, two of the three models failed to yield detection for Rx5Day for the North America mean. Finally, the authors used Total Least Squares, an estimation method known to overstate signal detection results (CWG Section 8.3.2). Here again, this is not “robust” evidence. Rather, it is suggestive, but other studies have found natural variability predominant. Both cited references utilized the implausible RCP8.5 scenario and began their “historical” observational records only in 1961.

Commented [SK6]: Need to explain this

4 RELIANCE ON *Ad Hoc* TIME SCALES FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We gave examples from analysis of river flooding (Section 6.1), heatwaves (Section 6.3) and extreme precipitation (Section 6.4) to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here we elaborate on these examples to illustrate a general point that NCA5 made inconsistent and *ad hoc* choices about time scales of analysis, weakening the validity of their conclusions.

4.1 Average and Extreme Precipitation

McKittrick and Christy (2019)⁷ showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s depending on location or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017).

In CWG Section 6.4 we presented analysis of updated data for the same locations and many more besides, in all cases finding considerable regional heterogeneity and lack of robustness of trends to use of long samples.

Commented [SK7]: Don't understand this wording

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion, instead it refers to changes “since the 1950s”, which we take to mean 1950 onwards (although NCA5 Fig. 2.8 suggests 1958 as the start date). For the present report we have extended the analysis even further now to include 141 stations across the US in the Pacific Coast, Midwest, Northeast and Southeast regions. We provide details in Appendix XX; here we note merely that once again it is possible to find trends that support the NCA5 position, but they are not robust to selecting longer or shorter time scales of analysis. Data from 1950 to 2024 yields many indications of increased average and extreme precipitation at individual stations and region-wide averages. But when using the entire data set (back to the 1890s or earlier depending on location) or the later subset (1980 to 2024) the trends become smaller, in many cases they become statistically insignificant, and occasionally they change sign. Only in the Northeast region are the post-1950 trends robust to focusing on the post-1980 interval.

Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

“Rainfall is becoming more extreme”

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity. The largest increase in the number of extreme precipitation days (defined as the top 1% of heaviest precipitation events) has occurred over the Northeast (an increase of around 60%) and Midwest (around 45%), along with increases of more than 10% in their annual and 5-year maximum amount (Figure 2.8). These changes have contributed to increases in river and stream flooding in

⁷ McKittrick, R., and J.R. Christy (2019). Assessing changes in US regional precipitation on multiple time scales. *Journal of Hydrology*, 578, 124074. [[HYPERLINK "https://doi.org/10.1016/j.jhydrol.2019.124074"](https://doi.org/10.1016/j.jhydrol.2019.124074)]

these regions. The increase in frequency and intensity of precipitation extremes is evident across a broad range of event durations (from 1 to 30 days) and return intervals (1 to 20 years), particularly east of the Rocky Mountains.

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US. Paleoclimate records derived from tree-ring growth provide evidence that summer moisture has increased over the past century in parts of New England, the central-eastern US, and the northern Mississippi River valley.

The following is a more accurate summary of what U.S. data show.

There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution to anthropogenic warming difficult.

Along the Pacific coast very few stations (1 or 2 out of 29) exhibit significant trends on any time scale in any metric and the region-wide trends are insignificant. In the Southeast region about 5 out of 24 stations exhibit positive trends in average and extreme precipitation metrics and the regional trends are likewise significant, but only on samples beginning in 1950. When the sample starts in 1873 or 1980 the trends weaken and become mostly insignificant. In the Midwest region nearly half the stations exhibit positive and significant trends in average precipitation since 1893 (23 of 61) and 1950 (28 of 61) but the trends weaken after 1980: only 6 of 61 locations are significant and the region-wide trend is insignificant. These positive trends reflect the dryness of the 1930's Dust Bowl era. Regional trends in max and 99th percentile exceedances are insignificant post-1893 and -1980 but the latter are positive and significant post-1950.

In the Northeast region 12 out of 27 stations exhibit positive and significant increases in average precipitation post-1888, post-1950 and post-1980 (10 of 27) and the regional trend is positive and significant in all three intervals. The regional number of 99th percentile exceedances has a positive trend post-1950 and post-1980 but not post-1888. The significant positive trends post-1980 are concentrated in NH but are insignificant elsewhere.

Consequently, precipitation in the U.S. exhibits considerable regional and temporal variability. Relatively more places became wetter than drier. The general pattern in the Midwest and Northeast since 1950 favors increased precipitation depending on the location, although trends since 1980 tend not to be statistically significant.

4.2 Heatwaves

There are mixed (and somewhat convoluted) messages in NCA5 regarding the notion that hot extremes are increasing in CONUS. NCA5 Chapter 2 offers these statements about extremes in heat on pg. 2-16:

[Key Message 2.2] Extreme Events Are Becoming More Frequent and Severe

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

And later on pg. 2-17

The Risk of Temperature Extremes Is Changing

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Several major heatwaves have affected the US since 2018, including a record-shattering event in the Pacific Northwest in 2021. The western US has been particularly affected by extreme heat since the 1980s (Figure 2.7), experiencing a larger increase in days over 95°F, as would be expected given the greater warming in that region relative to the eastern US. By contrast, the number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator (<https://www.globalchange.gov/indicators/heat-waves>) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

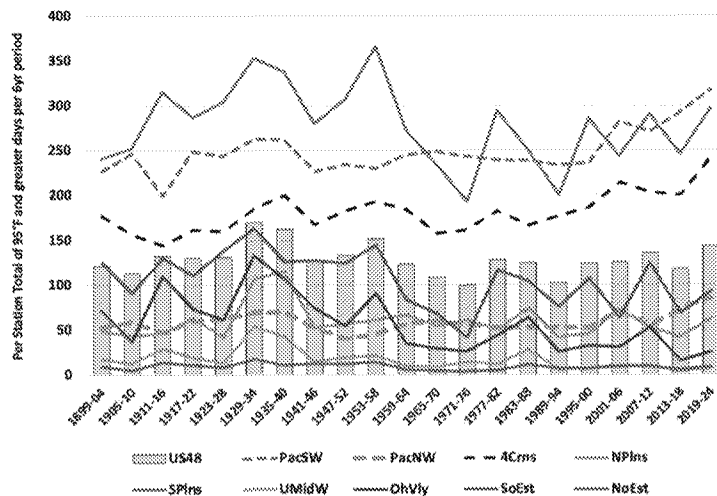
Nighttime temperatures are rising faster than daytime temperatures, and the number of nights where the temperature never falls below 70°F is increasing everywhere in the US except the Northern Great Plains (Figure 2.7). The extent of CONUS experiencing hot summer nights is growing at a faster rate than the extent experiencing hot summer days.

While these statements might be factually correct, they are misleading because they are factually incomplete. Much of NCA5's heat discussion focused on the West since the 1980's and on rising nighttime temperatures since the 1960's; the long-term decline in heat extremes in most of CONUS is barely mentioned. We also note the convoluted reasoning in the quote above that hot extremes are apparently due to "greater warming" in the western region than experienced elsewhere and that declining hot extremes elsewhere are "due to summer cooling trends". Of course, the real question is "What caused the warming *and* cooling trends?"

These heat issues were addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures (10's of degrees) are driven more by the chaotic behavior of natural variability than the small forcing by enhanced concentrations of CO₂. The CWG25 conclusion is that for both (a) hot days ($\geq 95^\circ\text{F}$) and (b) number of days in heatwaves, the current decade is experiencing no more than was experienced 100 years ago. For example, in the 30-year period 1925-1954, representing only 23% of the 1899-2024 data record, CONUS experienced 33% of the total heat wave days. The most recent 30-years experienced 24%, almost exactly that expected by chance.

Thus, the claim “multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal (to 1899) and spatial (entire CONUS) domains to evaluate the data that is available (Chapter 6 Fig. 6.3.6 of CWG25).

The figure below displays the occurrence of days $\geq 95^{\circ}\text{F}$, showing the increase in the three western regions and declines elsewhere. The trends in both heatwave days and hot days are (insignificantly) negative for CONUS as a whole.



Number of days $\geq 95^{\circ}\text{F}$ in 6-year periods (1899-2024) for nine CONUS regions (lines, dashed positive trends, solid negative trends) and full CONUS (bars).

It is clear that summer nighttime temperatures have risen rapidly since 1960 nearly everywhere, and especially in the largest cities. However, and not explicitly pointed out in NCA5, this observation is more a consequence of the urban heat island effect (which has greatest impact on nighttime temperatures and on stations changing from rural to semi-rural, as discussed in Chapter 6 of CWG25) and the choice of starting in the 1960's, the coolest decade since the 1910's.

In attributing claims of rising heat extremes to GHG concentrations, the NCA5 concentrated on the West but is silent on the attribution of declining heat extremes in the eastern two-thirds of CONUS (the statement “due to summer cooling trends” does not suffice) or the major role that the increasing growth of infrastructure around the stations exerts on nighttime temperatures. The scientific method requires that one deals with all the available evidence, not simply a small portion that agrees with a claim. In this instance the NCA5 falls short of rigorously demonstrating that rising GHG concentrations are responsible for the observed changes (or lack thereof) in hot extremes in CONUS; those are more fully explainable by natural variability (1930's Dust Bowl, cool 1960's) and urbanization (nighttime warming.)

The NASEM Review provided few comments on the explicit issues of assessing the changes in extreme temperatures. Much of its review focused on social and policy issues (e.g., Comments on

Equity and Justice), rather than on the confidence we have in the scientific assumptions that prompt the social and policy discussion. We assess that the NASEM review lacked the usual rigor of challenging questionable claims and analyses. Our analysis of selected comments from the NASEM review follows.

Page 42 of the NASEM review states:

[The chapter [2] meets the requirements of Section 106 of the GCRA.]

Commented [SK8]: Say on which page of the NASEM review this appears

This NASEM statement is of concern as the NCA5 chapter did not thoroughly address natural variability nor did it assess the full climate record available for analysis, which would better quantify natural variability. Chapter 2 actually downplays natural variability by claiming unsubstantiated skill in attributing recent extremes to human causes. For example, the Introduction of NCA5's Chapter 2 states,

"...recent advances in attribution science (KM [[HYPERLINK "https://nca2023.globalchange.gov/chapter/3"](https://nca2023.globalchange.gov/chapter/3) \l "key-message-3" \t "_blank"]) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."

Yet CWG25 demonstrates that this particular event would have happened in any case and that for CONUS, hot extremes are no more frequent now than they were in the past.

As another example, page 42 of the NASEM review offers

...the discussion and references regarding the role of natural climate variability and its regional differences are missing.

[This comment is correct, but difficult to find explicit comments on in the NCA5 given that NCA5 neglected to examine over half of the available CONUS climate record which begins in the late 19th century – a period obviously dominated by natural variability. While NCA5 occasionally nods to natural variability, that is usually followed by a "however" to emphasize human influence. One example is the statement just before the claim mentioned above, NCA5:

Commented [SK9]: Need to clarify this text

"There has always been extreme weather, which occurs even in an unchanged climate due to the natural variability of the Earth system. However, recent advances in attribution science (KM [[HYPERLINK "https://nca2023.globalchange.gov/chapter/3"](https://nca2023.globalchange.gov/chapter/3) \l "key-message-3" \t "_blank"]) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."

And yet another example from page 43 of the NASEM review:

"Extreme Events Are Becoming More Frequent and Severe."
Key Message 2.2 is another generally well written key message. However, while the title of this key message includes the word "risk," the key message is exclusively about hazard. The Committee suggests rewriting the key message title to more accurately reflect the discussion on hazards.

[
The review appears to accept the NCA5's use of data records going back only to the 1960's and 1980's since it makes no critical remarks about the NCA5's neglect of the available evidence to assess longer

time scales and the broader geographic area (CONUS). Rather, the NASEM review of Key Message 2.2 is only concerned about the title rather than its misleading content.]

Commented [SK10]: Seems redundant to prior criticisms

And as a final example, page 44 of the NASEM review offers:

It is also important to point out that the influence of natural climate variability becomes particularly strong when the climate trend is computed based on short periods of time or small geographic areas.

Yet this comment was largely ignored in the NCA5 final text.

5 INADEQUATE TRACEABLE ACCOUNTS

Beginning with the NCA3, every NCA has included a “Traceable Accounts” section at the end of each chapter. A description from the NCA5:

“Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team’s expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.”

The Traceable Accounts for each Chapter and Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

These sections could in principle address the NCA’s statutory requirement to discuss scientific uncertainties. Further, they could help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5’s Chapters 2 and 3 are uneven, often superficial and non-informative.

Here is an example from Chapter 2:

Key Message 2.2: Extreme Events are Becoming More Frequent and Severe.

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*). Drought risk has been increasing in the Southwest over the past century (*very high confidence*), while at the same time rainfall has become more extreme in recent decades, especially east of the Rockies (*very high confidence*). Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*). More frequent and larger wildfires have been burning in the West in the past few decades due to a combination of climate factors, societal changes, and policies (*very high confidence*).

The “Description of the Evidence Base” offers two paragraphs, the first summarizing the findings and the second paragraph a generic description of the types of data that can be used for storms. “Major Uncertainties and Research Gaps” focuses on the uneven distribution across US populations due to

differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data, except from reanalysis products. But the most astonishing deficiency is in the “Description of Confidence and Likelihood”, which reads

“Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.”

There is no reference to journal publications or a specific data set supporting this high confidence conclusion.

In Chapter 3, there are substantial inconsistencies between the Traceable Accounts for the different Key Findings. Key Message 3-1 reads “Human activities have caused global warming” and for Confidence and Likelihood offers

“There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period.”

Yet its Uncertainties section addresses only uncertainties in radiative forcing of greenhouse gases.

By contrast, Key Message 3-4 is that “Humans are changing Earth System processes.” Its Traceability Analysis is arguably the most scientifically credible text in the entire Chapter, as the Description of Evidence Base reads:

“In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals”.

and its Major Uncertainties and Research Gaps section reads:

“For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.”

[As part of the Traceable Account: “Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.” Upon clicking on the eyeball icon above a particular figure, a Contact US email appears, addressed to the USGCRP.

No attempt was made to send a email to elicit the Metadata information, but it is clear that this information is not readily accessible online.]

Commented [SK11]: Not clear we want this as USGCRP has been disbanded and nobody's home to answer the mail.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.

6 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to “project major trends for the subsequent 25 to 100 years,” the NCA relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.”

NCA5 makes the following observations about the scenarios they use:

“NCA5 authors were advised to assess the full range of scenarios available.”
(Front Matter)

“Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency.”
(Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue the NCA5 otherwise ignored the problem. A keyword search of the NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, ten NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios.

The problem of relying on extreme scenarios is particularly acute for sea level rise projections. The sea level rise scenarios used in the NCA5 do not relate directly to the SSP emissions scenarios, but to specified amounts of sea level rise by 2100. Table 4 of NCA5’s “Guide to Using this Report” shows that Low is 0.3 m (0.98 feet), Intermediate-Low is 0.5 m (1.64 feet), Intermediate is 1.0 m (3.28 feet), Intermediate-High is 1.5 m (4.92 feet), and High is 2.0 m (6.56 feet).

Considering only projections representing processes in whose quantification there is at least medium confidence, the IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m for the (5th–95th) percentile range, for all scenarios ranging from RCP2.6 to RCP8.5. The IPCC AR6 cites values as high as 2.4 m at the upper end of the 95th percentile range for RCP8.5, if estimates include the hypothesized Marine Ice Cliff Instability (*low confidence*). The corresponding

Commented [SK12]: The yellow highlighted text is an alternative to the blue highlighted text following. I don't know which is the most recent version - Judy needs to weigh in.

The range of sea level rise scenarios considered by the NCA5 includes Intermediate-High (is from 1.5 m) and High (to 2.0 m) values that associated with the implausible extreme emissions scenario RCP8.5 and processes in which there is low confidence in understanding. The NCA5/NCA5 neglects to include plausible lower scenarios, such as 0.2 m cited by the IPCC, that which also corresponds to the average rate of sea level rise over the past century.

With regards to actual predictions of sea level rise, Chapter 9 of the NCA states: “Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2).” These values of sea level rise encompass the

Intermediate scenario to values slightly higher than the High scenario from Table 4 << which Table 4?

Global sea level rise projections to 2050 relative to a 2000 baseline can be evaluated with respect to the observed global sea level rise from 2000-2024, which is approximately 3.39 inches (0.28 feet). [HYPERLINK "https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level"] Hence it is inferred that NCA5 is projecting values of sea level rise between 2025 and 2050 that are 3.5 to 5.8 times the rate observed during 2000-2024.

Chapter 9 further states: "Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches." This analysis accounts for the observed sea level rise between 2000 and 2020. << But they say it's relative to 2020.

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Considering only projections representing processes quantified with at least medium confidence, the IPCC AR6 assessed global mean seal level projections for 2100 to fall between 0.2 and 1.6 m for the 5th–95th percentile range, for all scenarios ranging from RCP2.6 to RCP8.5. The IPCC AR6 cites values as high as 2.4 m at the upper end of the 95th percentile range for RCP8.5, if estimates include the hypothesized Marine Ice Cliff Instability (low confidence).

Commented [SK13]: The blue text is an alternative to the yellow. Judy to decide.

NCA5's Intermediate-High (1.5 m) and High (2.0 m) scenarios thus correspond to the implausible extreme emissions scenario RCP8.5 and poorly understood processes. Yet NCA5 neglects to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which corresponds to the average rate of sea level rise over the past century.

Chapter 9 of the NCA states:

"Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2)."

These values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the [HYPERLINK "https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level"] global sea level rise from 2000-2024, approximately 3.39 inches (0.28 feet). NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000-2024.

Chapter 9 further states: "Looking toward the future, an 11 inch 28 cm average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches." [This analysis accounts for the observed sea level rise between 2000 and 2020.]

Commented [SK14]: Don't understand what this is saying?

With regards to confidence levels, NCA5 Chapter 9 Traceable Accounts states:

"There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050"

Unfortunately, neither the statement nor the context distinguishes whether this refers to global sea level rise or US average sea level rise, although it is inferred to refer to the former.

In summary, the NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios nor to global warming levels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes for which there is low confidence. Projections to 2050

require rates of sea level rise from 2025 to 2050 that are more than three times the rate observed during 2020-2024. Further, the NCA5 ascribes *high confidence* to these sea level rise projections.

The inclusion, and even the focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 BIASED SELECTION OF REFERENCES

-details

8 SUMMARY: EVALUATION OF THE NCA5

8.1 Pertinent aspects when evaluating in light of statutory requirements

- not our remit to make a ruling but here are aspects to consider in light of statutory requirements

8.2 Evaluation from the perspective of expert users of the report

- we have deep knowledge of the topics surveyed by the NCA5 authors
- we do not have confidence that the report was balanced and comprehensive
- we can point to many specific instances in which the report did not exhibit an appropriate level of quality or integrity as a scientific document
- we have reason to believe the whole process, from author selection to handling of expert reviews, was biased towards reinforcing foregone conclusions and alarmist messaging

8.3 Evaluation from the perspective of citizens interested in good policymaking

- Public concerns about climate change are valid, as are concerns about cost of living, economic growth, employment, etc.
- We share the general concern that elected officials and those who serve them have the best information available when making important decisions around energy and climate policy
- NCA5 was a missed opportunity: it could have been a valuable input to that process but it did not turn out that way
- consequently its usage is unlikely to lead to better decisions and would more likely increase the error rate in policy formation and we recommend it not be used for policymaking purposes.

APPENDIX 1: Kratsios charge letter

APPENDIX 2: Seth's letter on statutory requirements for NCA5

[APPENDIX 3: Analysis of 141 U.S. Longterm Daily Precipitation Records.]

Commented [SK15]: Needs at text explanation of what's being shown

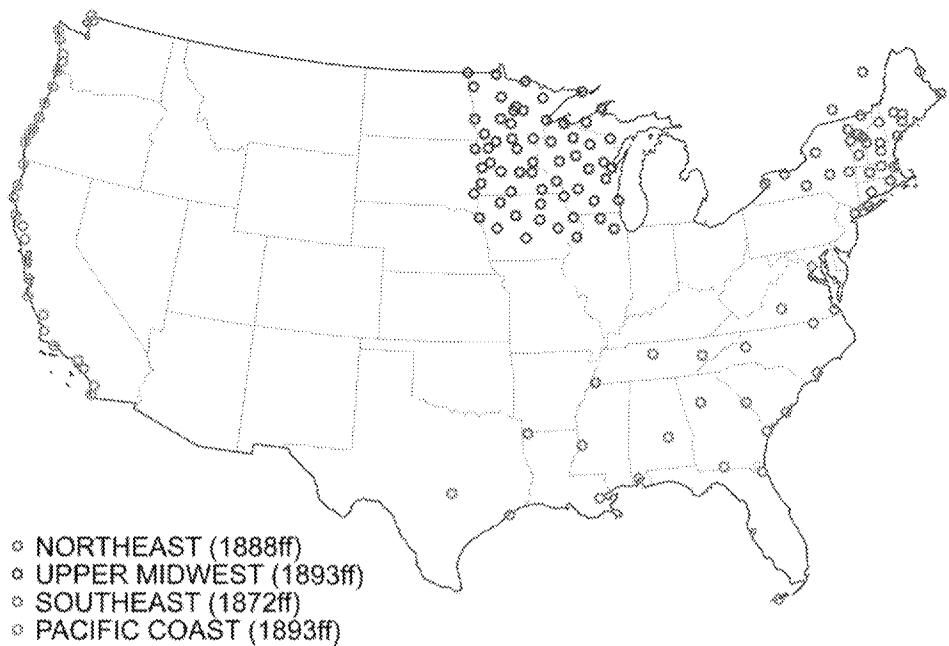


Figure. Stations used in the following analyses.

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure
Column 2: Number of stations in that region
Column 3: Count of stations exhibiting a significant positive trend
Column 3: Count of stations exhibiting a significant negative trend
Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)

Number of 99 th pct exceedances	29	1	0	(-)
--	----	---	---	-----

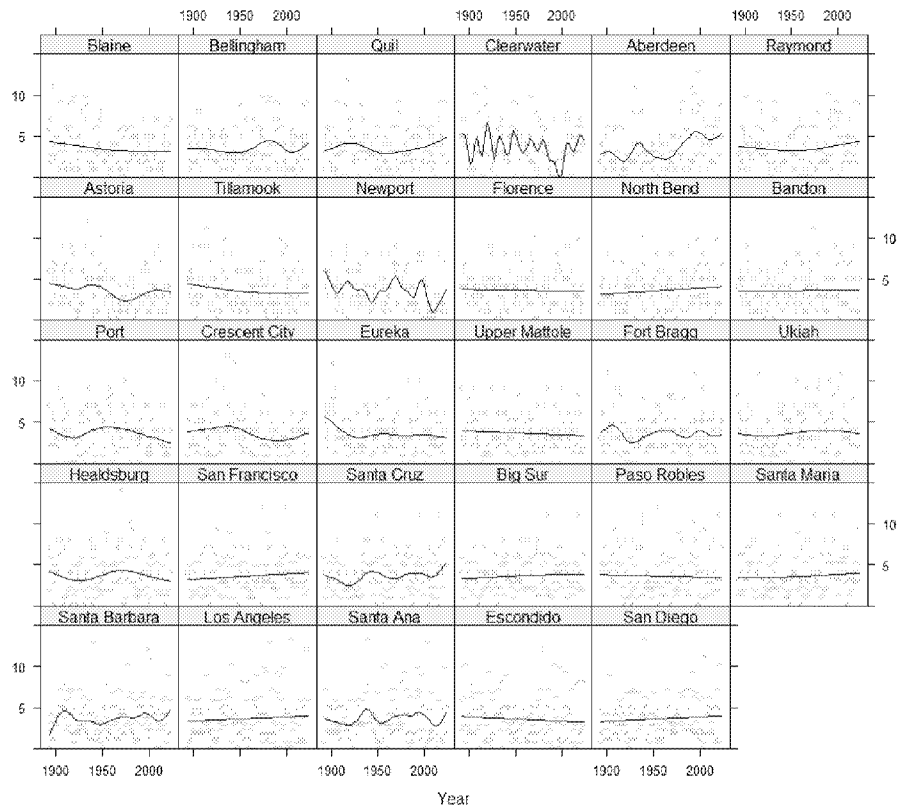
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

Annual No. 99th Percentile Exceedances PC 1893-2024



SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

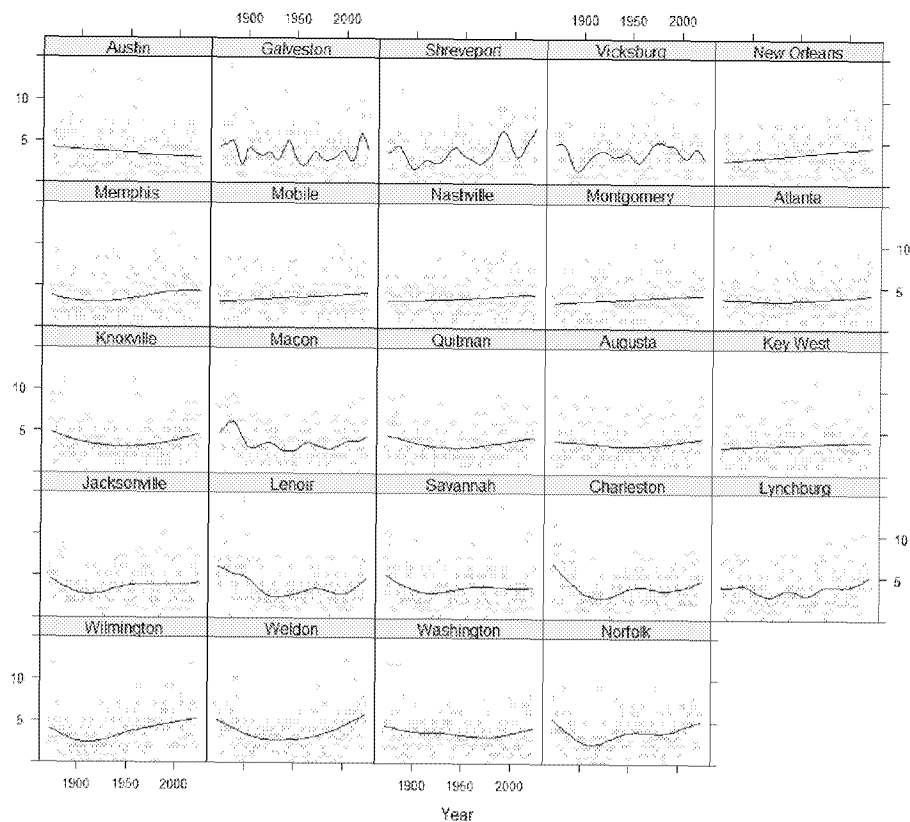
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

Annual No. 99th Percentile Exceedances SE 1873-2024



MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

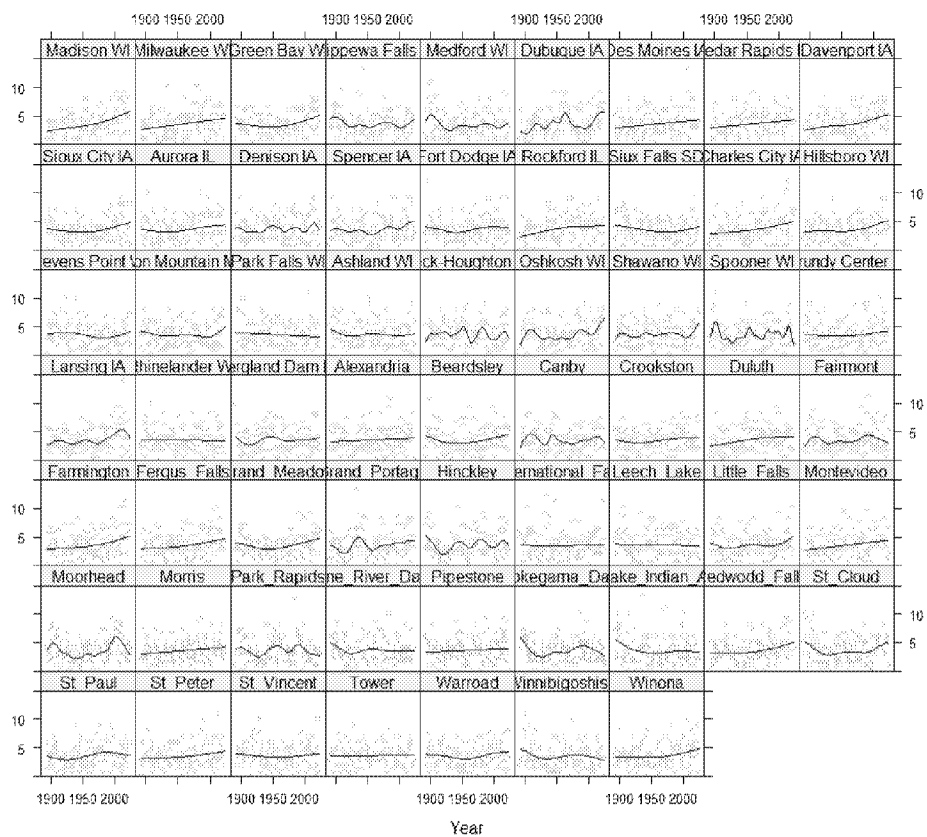
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

Annual No. 99th Percentile Exceedances MW 1893-2024



NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

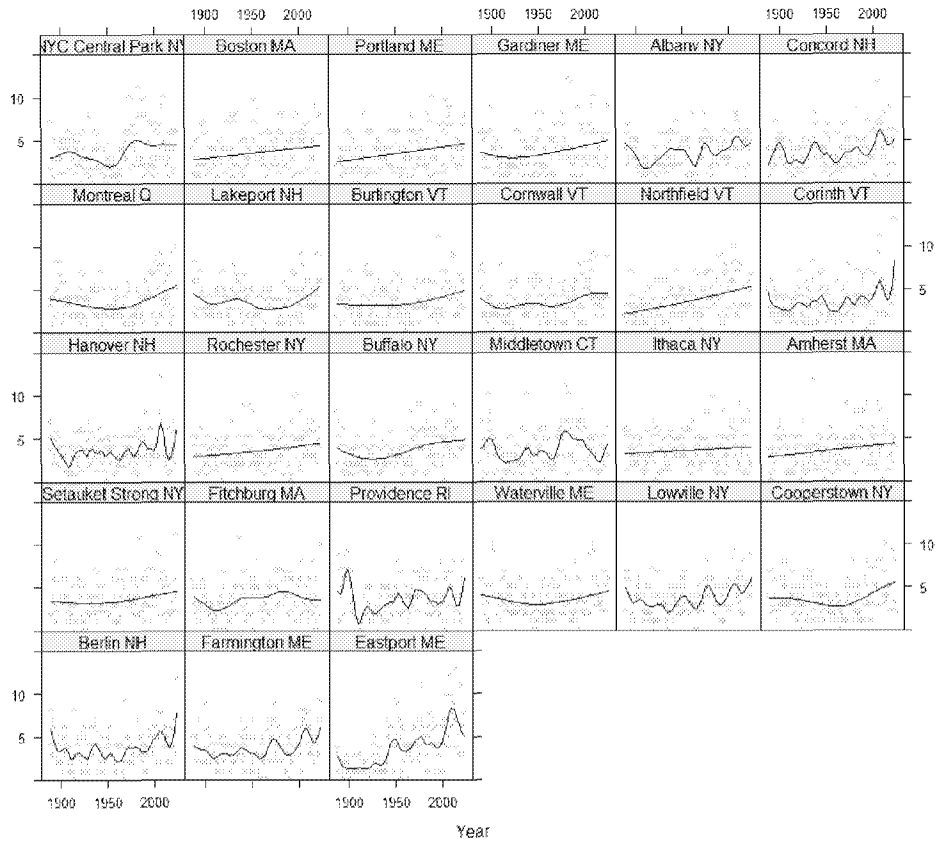
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

Annual No. 99th Percentile Exceedances NE 1888-2024



Review of the Fifth National Climate Assessment

[TOC \O "1-3" \H \Z \U]

1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix XX) that we assess the suitability of the Fifth National Climate Assessment for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, NASEM review of the Third Order Draft and the USGCRP responses to the review. We have drawn upon our long experience working on advisory reports, including for the NASEM, IPCC and other organizations, as writers, reviewers and project leaders.

Our report begins with background on the National Climate Assessments. We then discuss the standards by which we have assessed NCA5, followed by specific deficiencies that we have identified

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of the science as of its publication date in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted "CWG25"). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

1.2 About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change, but also sought to identify potential adaptation measures and identify the highest priorities for future research.
- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National

Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.

- NCA4 (2017/2018) was an expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis. NCA5’s self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points. Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

In Appendix XX we include a letter of guidance from the Office of General Counsel, U.S. Department of Energy, summarizing the extent of statutory requirements governing USGCRP work products in general and NCA products in particular.

We can summarize the standards applicable to the NCA as follows:
- details.

Beyond the statutory requirements we draw attention to two other pertinent standards. President Trump’s executive order of May 23, 2025, “[[HYPERLINK "https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/"](https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/)]" enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some have found them [[HYPERLINK "https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science"](https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science)].

When scientific reports are being assembled that will be highly influential on climate policymaking there are other desiderata, including statements about the strength of climate knowledge. The IPCC's approach is based on judgment of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include (Aven 2017)¹:

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns

Good climate and energy policies will balance the risks and benefits of a changing climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a unique responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.

In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to "save the planet." So it is not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem in a 1980 editorial² that resonates eerily four decades later:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

¹ Aven, Terje (2017) "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Application to Risk Matrices." *Reliability Engineering & System Safety* 167 (November 2017):42-48 [HYPERLINK "<https://www.sciencedirect.com/science/article/pii/S0951832016306950>"]

² Handler, Philip (1980) Public Doubts About Science. *Science* 208(4448) p. 1093 [HYPERLINK "<https://www.science.org/doi/10.1126/science.208.4448.1093>"]

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1.4 When Peer-Review Fails

Peer-review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, NCA reviewers self-select on a volunteer basis whether to provide comments and what parts of the report to read, whereas in academic journals Editors recruit reviewers and assign them to specific papers. There is no guarantee that any particular section of an NCA report was reviewed by anyone, let alone by someone with a different perspective than the authors. This is a problem with NCA and IPCC reports since over the years many potential reviewers have given up making the effort, because their input has systematically been ignored. Second, NCA authors have near complete authority whether to accept or reject review comments. Here, for example, is how a review comment critical of a section of the NCA5 draft was handled by the authors:

By contrast in academic journals the Editor mandates the author to respond and the reviewer gets to assess its adequacy. Once an NCA chapter author team has been selected publication of their work is guaranteed, whereas academic journals routinely reject papers if they do not pass review.

These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were “peer reviewed”. But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a Figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

As we pointed out in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Considering cold and hot extremes together the U.S. the U.S. climate has become more moderate over time. NCA4’s Part I (Climate Science Special Report, CCSR) says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:

Record Warm Daily Temperatures Are Occurring More Often

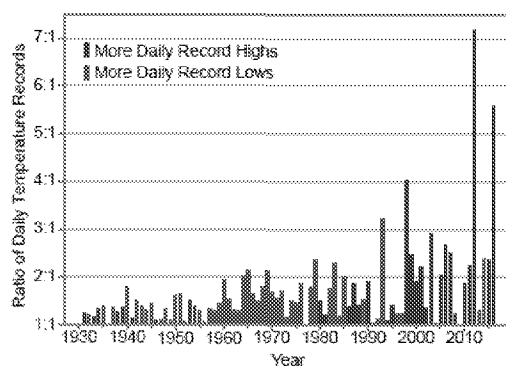
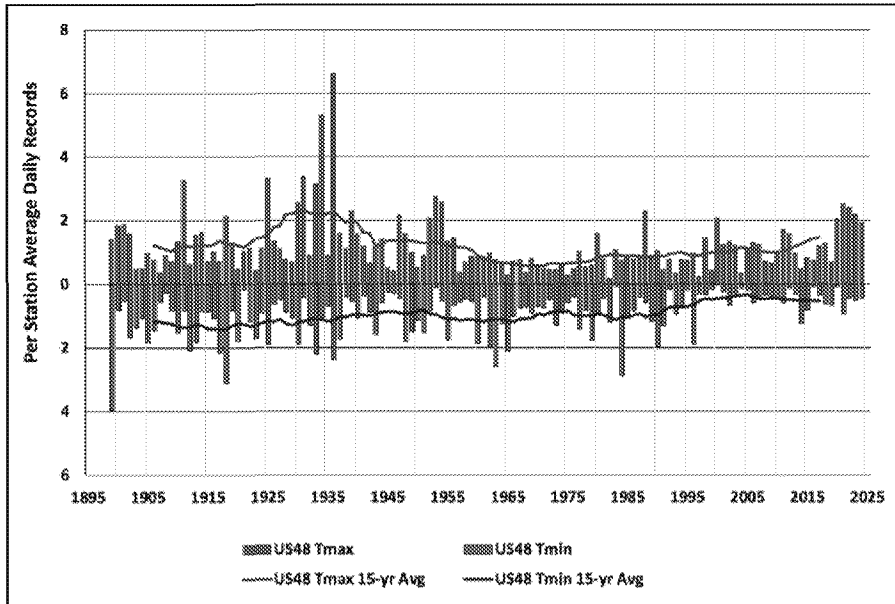


Figure ES.5: Observed changes in the occurrence of record-setting daily temperatures in the contiguous United States. Red bars indicate a year with more daily record highs than daily record lows, while blue bars indicate a year with more record lows than highs. The height of the bar indicates the ratio of record highs to lows (red) or of record lows to highs (blue). For example, a ratio of 2:1 for a blue bar means that there were twice as many record daily lows as daily record highs that year. (Figure source: NOAA/NCEI). From Figure 6.5 in Chapter 6.

The Figure appears to validate the claim that record warm daily temperatures are occurring more often. But the underlying data do not: they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as NCA4 Figure 6.4 later shows. Figure ES.5 does not show what its title implies: these are not simple counts of cold and warm extreme events; instead they are ratios of the two. In fact both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes increased. By graphing the ratio in this way the NCA4 created a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis of the data – defining each record as the singular extreme in the history, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the extreme Tmax records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio of heat to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of the NCA4 Figure ES.5.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3. **DON'T BOLD THE CAPTION**

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The National Academies' expert review panel [[HYPERLINK "https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report"](https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report)] the discussion of temperature extremes in a [[HYPERLINK "https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf"](https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf)] of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) [[HYPERLINK "https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf"](https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf)] to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The "new figure" referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies' panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn't have survived to publication. And the figure's problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

While the following statement has far less headline potential than that from the CSSR's page 19 quoted at the beginning of this box, it has advantage of being correct:

~~There have been some changes in temperature extremes across the contiguous United States. The annual number of high temperature records set shows no significant trend over the past century nor over the past 40 years, but the annual number of record cold nights has declined by a factor of 4 since 1895, somewhat more rapidly in the past 30 years.~~

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Commented [A2R1]: R^2 is 0.02, so not significant for 1978-2017.

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With this background we now present our critique of NCA5.

2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND NON-SCIENTIFIC TONE

NCA5 Chapter 1 “Overview” holds a prominent place in the Report since it summarizes the whole report and is the only section that many will read. Although the later Chapters of NCA5 contain much sound scholarly content, Chapter 1 is marred by a pervasive tone and language that aggressively promotes emission reduction policies. As such, this chapter adds an imprimatur of scientific authority to oversimplified declarations of opinion about public policy. Here we cite a few examples that are particularly egregious.

Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that: all warming is anthropogenic in origin, all warming is bad and causes economic damage, warming causes extreme weather to intensify. Such sweeping generalizations go well beyond what science has or can establish. It also refers to growing risks without saying whether they were large to begin with: a small risk that grows may still be a small risk. A scientifically-sound version of this paragraph would instead say something like the following:

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The Earth is warming because of a combination of natural and anthropogenic influences. This warming will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. Some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases might slow the warming although such policies have proven to be costly and disruptive, so any climate actions to be weighed against the potential benefits.

On the next page the Overview goes on to say:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits...”

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms, indeed (as is acknowledged in Chapter 19 on Economics) in some cases there will be benefits. Nor is climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers.

Pages 8 and 9 promote renewable energy options by noting, correctly, that the levelized costs of wind/solar generation have fallen sharply since 2010. This is proposed as rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

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Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) can substantially increase the cost of electricity. Further, there are yet unmet synchronization challenges in transmission grids with heavy penetration of wind and solar power. Here again it is advisory malpractice not to acknowledge these facts.

Page 14 presents future emission scenarios with the following description: "Climate modeling experts develop global climate projections for a range of plausible futures." The word "plausible" is applied to all the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The figure does not contrast observed emissions against ~~model-previous~~ projections nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as "plausible" the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline "business-as-usual" future.

Page 17 introduces the discussion of risks from extreme weather events by saying "Harmful impacts from more frequent and severe extremes are increasing across the country." This creates the impression that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the value of assets at risk, ~~we could criticize Figure 1.6, which uses an anecdote to support its 1200 claim.~~

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Page 17 (and elsewhere) it then invokes the NOAA Billion Dollar Dataset as an indicator evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product. Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends and they should have taken care not to conflate extreme weather metrics with economic trends.

Page 23 states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points

not only to the willingness of NCA5 authors to promote hysteria, but also the ineffectiveness of the review process at not ensuring such statements are removed.

The tone of the Overview chapter hints at the priorities that governed the writing of the report as a whole. As a crude indicator of these priorities, word searches of the full document revealed the following occurrences:

Term	Number of occurrences
Forcing	111
Uncertainty	384
Watts	19
Culture/culturally	854
Equity/equitable	572
Indigenous	890
Sustainable	295
Racism/racial	153

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~~DELETE THE FLOOD EXAMPLE. MUCH WEAKER THAN THE OTHERS THAT ARE FOCUSED ON POLICY AND ADVOCACY~~

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~~We won't try to cite all the remaining examples of advocacy and hyperbole in the Overview chapter; one more example will suffice. Page 26 states "Increasing flooding puts more people and assets at risk." The accompanying figure contrasts model-projected flood losses by county in 2050 to that observed in 2020 as estimated in Wing *et al.* (2022)³. Hence the evidence for the claim is not currently-observed trends, rather it is a model-generated projection of changes. But current trends in U.S.-based flooding reveal a more complex picture with a general overall trend towards less flooding. The Environmental Protection Agency's "Climate Change Indicators: River Flooding" webpage⁴ shows maps both of flood magnitude and frequency. Both show more regions experiencing declines over 1965-2015 than increases. Hence current trends indicate generally declining U.S. flood risks, but the NCA5 Overview not only fails to mention this but declares the opposite based on a single study presenting model-generated forecasts of flood activity decades in the future.~~

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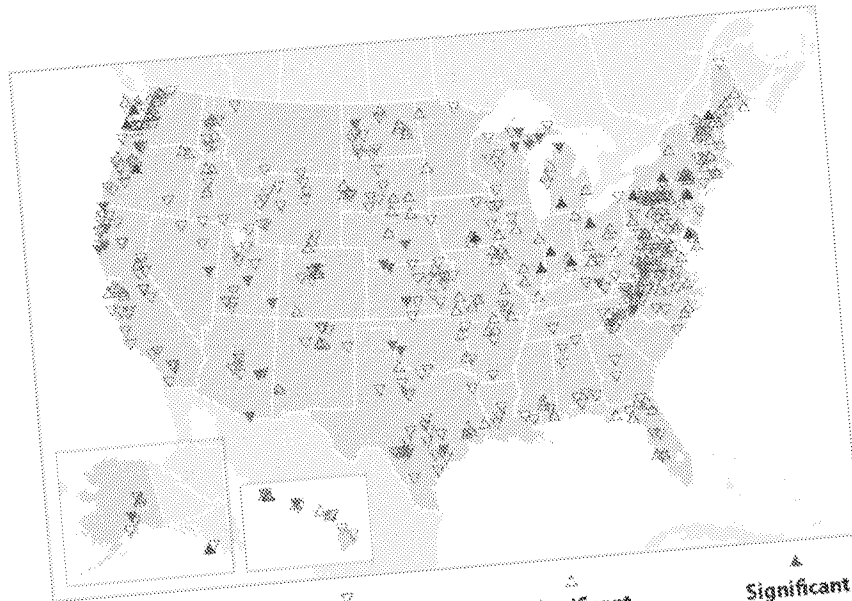
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³ Wing, Oliver, William Lehman, Paul Bates *et al.* (2022) Inequitable patterns of US flood risk in the Anthropocene. *Nature Climate Change* 12:156–162 [HYPERLINK "<https://www.nature.com/articles/s41558-021-01265-6>"]

⁴ [HYPERLINK "<https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding>"]



Significant decrease

Insignificant decrease

Insignificant increase

Significant increase

U.S. Flood magnitude trends 1965-2015

Source: [HYPERLINK "<https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding/>"]

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3 ONE-SIDED OVERSIMPLIFICATIONS IN SCIENCE SUMMARY
CHAPTERS OVERCONFIDENCE WHEN STATING CONCLUSIONS

~~Chapters 2 (Climate Trends) and 3 (Earth Systems Processes) form the scientific core of NCA5. As we will show in the following examples they fail to meet statutory requirements to discuss scientific uncertainties and the role of natural variability, and they fail to meet the more stringent implicit standards expected of a policymaking policy-informing report.~~

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3.1 ~~Inappropriate Certainty Grading~~Inflated Certainty Levels

A general pattern in the NCA5 is overconfidence in stating conclusions. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

The NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of the NCA5 states that “confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.”

Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in the conclusions.

Even within the context of this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. Several illustrative examples are provided.

Key Message 3.1 Traceable Account states: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era." Compare this statement with statements from the IPCC AR5 and AR6:

AR5: "It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together." (IPCC, 2013)

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AR6: "The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warmings since 1979." (IPCC, 2021)

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While the NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, the AR5 refers to "*more than half* of the observed warming" and the AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

NCA5 Key message 2.2:– "Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*)."

No justification is provided in Chapter 2 for the *high confidence* conclusion on higher storm surges or hurricanes causing heavier precipitation. The Traceable Accounts section, Description of Confidence and Likelihood states:—"Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have *high confidence* that storms are delivering more rainfall and high confidence that storm surges are becoming higher." In short, the NCA5 provides no observational basis or published research for their *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges; and does not meet its own standards for a *high confidence level*.

~~I WOULD DELETE THIS EXAMPLE. FIRST, THE NCA5 PRETTY MUCH PARROTS WHAT THE AR6 SAID, AND LEWIS WAS PROBABLY PUBLISHED AFTER NCA5 LITERATURE CUTOFF. THE SENSITIVITY STUFF IS GOOD FOR THE CWC REPORT, BUT NOT FOR NCA ASSESSMENT.~~

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~~3.2 Increased Lower Bound of Climate Sensitivity~~

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~~The promotional tone of Chapter 1 is carried forward into Chapter 3 (Earth System Processes) where states, on page 3-10, Key Message 3.2: states "The Estimated Range of Climate Sensitivity Has Narrowed by 50%". Referring to Equilibrium Climate Sensitivity (ECS) the section elaborates:~~

~~Recent improvements in the understanding of how climate feedbacks vary across timescales have narrowed the estimated *likely* range of warming expected from a doubling of atmospheric carbon dioxide by 50% to between 4.5°F and 7.2°F (*high confidence*). This uncertainty reduction results from advances in combining observations and targeted modeling results from nearly independent lines of evidence, each of which generally agrees on the values of ECS. The lines of evidence include 1) observed present-day variations on monthly to interannual timescales from which cloud and other climate feedbacks are~~

inferred; 2) observed temperature changes between the preindustrial period and present and associated relationships to ERF; and 3) estimated temperature and radiative forcing changes for multiple warm and cold periods in paleoclimate records.

The graphic summary on page 3-11 states

The reduced uncertainty in climate sensitivity and climate feedback has been achieved through unprecedented quantitative synthesis of evidence from observed changes over recent decades, the industrial era, and paleoclimate.

This is a very grossly inadequate description of the situation. The key development in AR6 was a reduction of confidence in the ability of climate models to identify ECS and the shift away from the model-based method the IPCC had relied on since AR1 in 1990. The IPCC instead turned to data-driven ECS estimation and specifically chose a single paper from the scientific literature, Sherwood *et al.* (2020⁵), for the purpose. It combined paleoclimate data, modern instrumental data and modern observations of climate processes, mainly cloud-related, that govern key feedbacks. Sherwood *et al.* used a subjective Bayesian method to determine the likely range of ECS values. The Bayesian approach begins with the researcher specifying a "prior", namely an expectation of what the answer will be before seeing the data. In this case the prior consists of an expected ECS range based on the researchers' subjective beliefs. Then the data are allowed to influence the ECS distribution and the final result is a weighted average of the assumed prior and the data-driven result. Sherwood *et al.* found a best (or median) ECS estimate of 5°F (3°C), which was close to previous model-based estimates but raised the likely lower bound by 1.7°F from 2.5°F to 4.2°F. The IPCC accepted this result and increased the best estimate to 3.1°C.

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The NCA5 was published in November 2023. Well before that, in September 2022, Lewis (2023) had been published online at *Climate Dynamics* presenting a forceful critique of Sherwood *et al.*⁶ One of Lewis' points was that Sherwood *et al.*'s result was dependent on their chosen subjective prior. Lewis recommended using an objective Bayesian method, which places primary weight on the data rather than the researcher's expectation. Using that and updated forcing data from AR6, Lewis estimated an ECS best estimate of 3.7°F (2.2°C) with a likely lower bound of 2.7°F (1.6°C).

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Hence, in contrast to the promotional language of Chapter 3 a more valid summary of the ECS literature as it stood at the time of writing the NCA5 would be what we wrote in CWG25 (emphasis added):

For the AR6, the IPCC placed primary weight on the results of Sherwood *et al.* (2020) that combined historical and paleoclimate proxies with the process-based approach and yielded a best estimate of 3.1°C with a likely range of 2.6-3.9°C. Lewis (2022) raised a number of concerns about this result, including methodological errors, outdated input values, and use of subjective versus objective Bayesian priors in the analysis. Lewis' analysis found that climate sensitivity is estimated to be much lower and better constrained than in the

⁵Sherwood, S. C., Bony, S., Boucher, O., Bretherton, C. S., Forster, P. M., Gregory, J. M., & Stevens, B. (2020). An assessment of Earth's climate sensitivity using multiple lines of evidence. *Reviews of Geophysics*, 58(4). [HYPERLINK "https://doi.org/10.1029/2019rg000678"]

⁶Lewis, N. (2023). Objectively combining climate sensitivity evidence. *Climate Dynamics*, 61(9-10), 3155-3163. [HYPERLINK "https://doi.org/10.1007/s00382-022-06398-8"]. The final citation for this paper is Lewis (2023) because the print edition did not appear until 2023, but the article was accepted in August 2022 and the online edition appeared and was in circulation in September 2022.

Sherwood *et al.* analysis—median 2.2°C (1.8–2.7°C in the 17–83 percent *likely* range, and 1.6–3.2°C in the 5–95 percent *very likely* range). The IPCC AR6 estimated only a 5 percent probability that ECS was below 2.3°C, whereas Lewis estimated it to be over 50 percent. The most recent publications on the debate between Sherwood *et al.* and Lewis further defend their respective positions: Sherwood and Foster (2024) and Lewis (2025).

~~I WOULD DELETE THIS EXAMPLE. WE HAVE ANOTHER MORE EFFECTIVE SECTION ON EMPHASIS ON EXTREME EMISSIONS SCENARIOS.~~

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~~3.3 Presenting New Emission Scenarios as a Scientific “Advance”~~

~~Chapter 3 pp. 13–14 treats the release of new emission scenarios as a scientific “advance” without addressing the failure of many previous scenarios to match reality or providing an honest assessment of the likelihood that the new ones are remain biased in the same way.~~

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Key Message 3.3 states “New Data and Analysis Methods Have Advanced Climate Science” and includes the following:

New scenarios of socioeconomic development, and their associated emissions and land-use changes, drive updated climate projections from Earth system models. The Scenario Model Intercomparison Project (ScenarioMIP) organized the main set of 21st-century projection experiments under the latest phase of the Coupled Model Intercomparison Project, CMIP6. These CMIP6 projections used newly developed scenarios based on Shared Socioeconomic Pathways (SSPs; Figure 3.4). Five SSPs represent alternative plausible trajectories of 21st-century GDP and population growth and the pace and pervasiveness of socioeconomic and technological progress within individual nations and across the world (see Table 3 in the Guide to the Report). SSP-specific drivers are used in integrated assessment models (IAMs) to simulate the corresponding evolution of the energy system and the resulting greenhouse gas trajectories. These are in turn used by ESMs to drive their 21st-century projections.

There is nothing wrong with NCA5 discussing the development of new emission scenarios which serve as inputs to climate change projections and impact studies. But it is a serious omission not to inform the reader of the failure of many previous IPCC scenarios to match reality and the tendency of the scenario groups to exaggerate near-term and long-term CO₂ concentration growth (CWG25 3.2.1). It is also a serious omission not to caution readers that many climate impact studies use RCP8.5 which by the time of NCA5 had already been heavily criticized in the literature.

The same section also reports the availability of new and larger model ensembles as a scientific advance, without addressing ways in which models are getting worse in some key respects (CWG Ch 5).

~~DELETE THIS SECTION. IT IS AN OBSCURE TOPIC AND DOESN'T OBVIOUSLY FIT IN THE OVERCONFIDENCE SECTION~~

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~~3.4 Uncritical Promotion of “Emergent Constraints”~~

~~Chapter 3 page 17 presents the topic of “emergent constraints” in uncritical terms.~~

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An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as “emergent constraints.” The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as a way to tie GCM behavior to climate observations in hopes of generating insight into real-world ECS. Climate models exhibit a wide range of sensitivities. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could check if the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a large proliferation of proposed correlations with little physical motivation. Many emergent constraints patterned on CMIP5 models failed to work on CMIP6 models (Schlund *et al.* 2020)². In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the Earth climate system. The result was that emergent constraints estimated on CMIP5 models widened the range of estimated ECS values when applied to CMIP6 models.

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Schlund *et al.* summarized the problem as follows:

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In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project. The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases. Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great “advance” that reduced uncertainty.

~~DELETE THIS EXAMPLE. THE IMPORTANT PART OF THIS EXAMPLE IS ALREADY IN SECTION 3.4~~ Increasing hurricane intensity.

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NCA5 Key message 2.2 states “Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*).”

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²Schlund, Manuel, Axel Lauer, Pierre-Gentine, Steven G. Sherwood, and Veronika Syring. (2020). Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6? *Earth System Dynamics* 11: 1233-1258 [HYPERLINK "<https://doi.org/10.5194/esd-11-1233-2020>"]

No justification is provided in Chapter 2 for the *high confidence* conclusion on higher storm surges or hurricanes causing heavier precipitation. The Traceable Accounts section, Description of Confidence and Likelihood states: "Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes; this is why the authors also have *high confidence* that storms are delivering more rainfall and high confidence that storm surges are becoming higher." In short, the NCA5 provides no observational basis or published research for their *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges, and does not meet its own standards for a *high confidence level*.

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3.2 Overstating Findings findings in Underlying underlying Sourcesources

3.5 ~~THIS ONE WORKS IN THE OVERCONFIDENCE CHAPTER, BUT THE EXAMPLES ARE NOT WELL DESCRIBED~~

Although we did not do a detailed audit of the NCA5's use of source material, a few spot checks turned up evidence of a pattern of overstatement.

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Chapter 2 page 11 reports on an increase in precipitation in central and eastern US some areas and attributes it to climate change:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

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based on a comparison of 2002-2021 average rainfall to the average over 1901-1960. Note that this a non-standard metric; we will discuss NCA5's inconsistent choices of time scales of analysis below. The change in this case is called a "trend" even though this is not how a trend is measured, and says that it is "attributable to climate change". The claims were attributed to the following paper:

~~WOULD BE BETTER TO PROVIDE A DIRECT QUOTE FROM THE NCA5~~

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- Knutson, Thomas and Fanrong Zeng (2018) "Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends" *Journal of Climate* 31(12)
[HYPERLINK "<https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml>"]

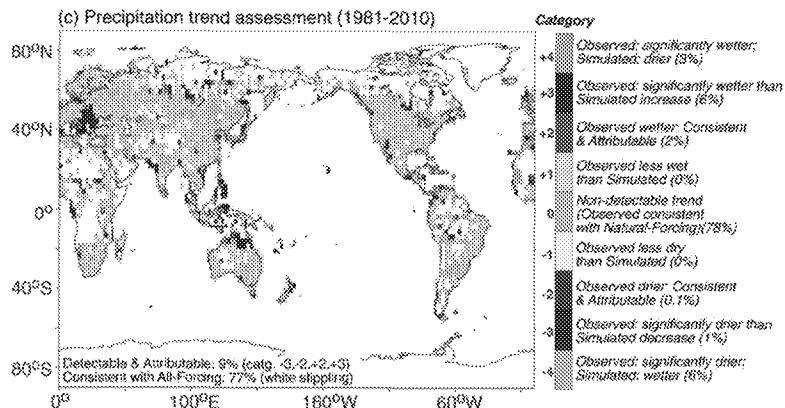
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But Knutson and Zeng did not say these things. ~~They~~ examined linear trends over 1901 - 2010, 1951 - 2010 and 1981 - 2010. ~~They~~ did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 - 1960, indeed ~~their study~~ was published in 2018 so it could not have. With regard to 1981-2010 trends its results were summarized in the following figure: they noted stronger trends in some areas but cautioned that such changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States:

Observed annual precipitation trends over the recent 30-yr period 1981-2010 ([HYPERLINK "<https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml>" \l "fig5"]) have generally stronger magnitudes (in mm yr⁻¹ decade⁻¹) than observed trends for 1901-2010 or 1951-2010. This is as expected since trends over a shorter period have stronger potential for occurrence of pronounced temporary trends due to internal variability alone. Only 9% of the analyzed area has detectable and attributable anthropogenic influence (categories -3, -2, +2, +3), which represents less than one-third of the fractional areal coverage of such trends for 1901-2010 (29%). ... Eight percent of the analyzed area has attributable anthropogenic increases (categories +2, +3), including parts of eastern Europe, northern Asia, northern Australia/Maritime Continent, and tropical Africa.
~~DON'T NEED THE FIGURE, CAN YOU PROVIDE RELEVANT QUOTE FROM KNUTSON PAPER THAT IS AT ODDS WITH NCA5 CONCLUSION~~

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Gray indicates no trends detected. Stippling means that there were no trends in the models either so the models and observations agreed in that respect. Detectable and attributable trends were found over only 9% of the land surface of the Earth. Over the US there are detectable trends over only a few regions in the Southwest.

Consider a 2nd example. NCA5 Chapter 2 page 18 states

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There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is attributed to two papers:

- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. [[HYPERLINK "https://doi.org/10.1126/sciadv.aao3354"](https://doi.org/10.1126/sciadv.aao3354)]

and

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- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308-13313. [[HYPERLINK "https://doi.org/10.1073/pnas.1921628117"](https://doi.org/10.1073/pnas.1921628117)]

Diffenbaugh et al. presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not "robust" evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something which even the IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using 3 GCMs, found "A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically." However, they noted large differences among the three models in their simulated precipitation changes. Also, 2 of the 3 models failed to yield detection for Rx5Day-5-day events for the North America mean. ~~Both cited references utilized the implausible RCP8.5 scenario and began their "historical" observational records only in 1961. Finally, the authors used Total Least Squares, an estimation method known to overstate signal detection results (CWG Section 8.3.2).~~ Here again this is not "robust" evidence, it is suggestive but other studies have found natural variability predominant. ~~Both cited references utilized the implausible RCP8.5 scenario and began their "historical" observational records only in 1961.~~

4 RELIANCE ON *Ad Hoc* TIME SCALES FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need to be careful regarding the choice of time scale when making claims about trends in extreme weather. We gave examples from analysis of river flooding (6.1), heatwaves (6.3) and extreme precipitation (6.4) to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here we elaborate on these examples to illustrate a general point that NCA5 made inconsistent and *ad hoc* choices about time scales of analysis, weakening the validity of their conclusions.

McKittrick and Christy (2019)⁸ showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017).

In CWG Section 6.4 we presented analysis of updated data for the same locations and many more besides, in all cases finding considerable regional heterogeneity and lack of robustness of trends to use of long samples.

4.1 Average and Extreme Precipitation

Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

“Rainfall is becoming more extreme”

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion, instead it refers to changes “since the 1950s”. Fig. 2.8 suggests 1958 as the start date. For the present report we have extended the CWG25 analysis even further ~~now~~ to include 141 stations across the US in the Pacific Coast, Midwest, Northeast and Southeast regions. We provide details in the Appendix; here we note merely that once again it is possible to find trends that support the NCA5 position, but they are not robust to selecting longer or shorter time scales of analysis. Data from 1950 to 2024 yields many indications of increased average and extreme precipitation at individual stations and region-wide averages. But when using the entire data set (back to the 1890s or earlier depending on location) or the later subset (1980 to 2024) the trends become smaller, in many cases they become statistically insignificant, and occasionally they change sign. Only in the Northeast region are the post-1950 trends robust to also focusing on the post-1980 interval.

The following is a more accurate summary of what U.S. data show.

⁸ McKittrick, R., and I.R. Christy (2019). Assessing changes in US regional precipitation on multiple time scales. *Journal of Hydrology*, 578, 124074. [HYPERLINK “<https://doi.org/10.1016/j.jhydrol.2019.124074>”]

There are regionally-heterogenous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution to anthropogenic warming difficult.

~~Along the Pacific coast very few stations (1 or 2 out of 29) exhibit significant trends on any time scale in any metric and the region-wide trends are insignificant. In the Southeast region about 5 out of 24 stations exhibit positive trends in average and extreme precipitation metrics and the regional trends are likewise significant, but only on samples beginning in 1950. When the sample starts in 1873 or 1980 the trends weaken and become mostly insignificant. In the Midwest region nearly half the stations exhibit positive and significant trends in average precipitation since 1893 (23/61) and 1950 (28/61) but the trends weaken after 1980; only 6/61 locations are significant and the region-wide trend is insignificant. These positive trends reflect the dryness of the 1930's Dust Bowl era. Regional trends in max and 99th percentile exceedances are insignificant post-1893 and 1980 but the latter are positive and significant post-1950.~~

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~~In the Northeast region 12 out of 27 stations exhibit positive and significant increases in average precipitation post-1888, post-1950 and post-1980 (10/27) and the regional trend is positive and significant in all three intervals. The regional number of 99th percentile exceedances has a positive trend post-1950 and post-1980 but not post-1888. The significant positive trends post-1980 are concentrated in NH but are insignificant elsewhere.~~

~~Consequently, precipitation in the U.S. exhibits considerable regional and temporal variability. Relatively more places became wetter than drier. In the Midwest and Northeast the general pattern since 1950 favors increased precipitation depending on the location, although trends since 1980 have not tended to be statistically significant.~~

~~KEEP IT FOCUSED ON THEIR MISREPRESENTATION OF EXTREME PRECIP~~

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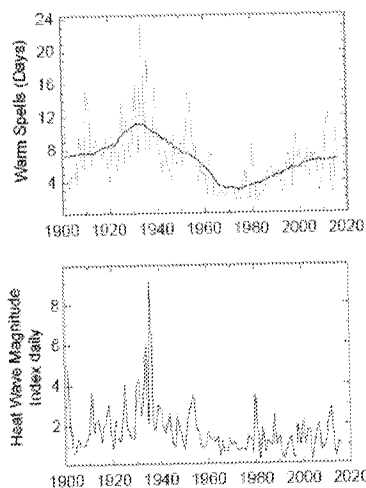
4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the whole of the 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies:

[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s.

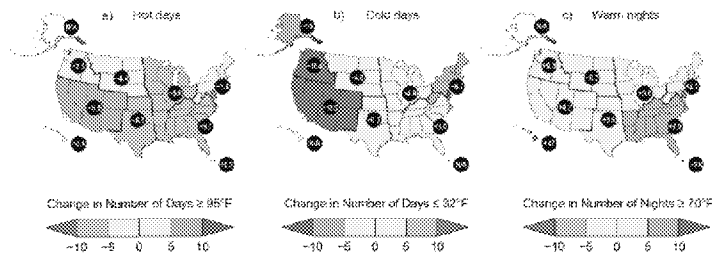
(NCA4 pp. 190-191)



U.S. Heatwaves since 1900. Source: NCA4 Figure 6.4

Contrast this careful and factual language with NCA5 Key Message 2.2: “Extreme Events Are Becoming More frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 reproduced below.

Observed Changes in Hot and Cold Extremes



Hot days have increased in the West, hot nights have increased nearly everywhere, and cold days have decreased.

Figure 2.7. Over much of the country, the risk of warm nights has increased while the risk of cold days has decreased. The risk of hot days has also increased across the western US. This figure shows the observed change in the number of (a) hot days (days at or above 95°F), (b) cold days (days at or below 32°F), and (c) warm nights (nights at or above 70°F) over the period 2002–2021 relative to 1901–1960 (1951–1980 for Alaska and Hawaii and 1956–1980 for Puerto Rico). Data were not available for the US-Affiliated Pacific Islands and the US Virgin Islands. Figure credit: Project Drawdown, Washington State University Vancouver, NOAA NCED, and CIRES NC.

Close inspection shows that this Figure contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of the NCA4. The time scale of analysis for this Figure is stated as the number of hot days, cold days and warm nights (respectively in panels a–c) over the period 2002–2021 compared to 1901–1960. Presumably (though not stated in the caption) the counts are per year. Notwithstanding Key Message 2.2 the leftmost panel shows that over most of CONUS the number of extreme heat days has decreased in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted since it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 chapter 2 elaborates on KM2.2 by saying (p. 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But it does not mention the decline elsewhere. On the next page (p. 17) it says:

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

Reference to a global trend seems to be an attempt to tie heatwaves to climate change, but then the obvious question, unaddressed by NCA5, is why only part of the U.S. follows it while most of the country is trending in the opposite direction. These issues were addressed in CWG25 Ch6, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by natural variability than the small extra forcing from the enhanced concentrations of CO₂. The data shown in CWG25 shows that in terms of both (a) hot days ($\geq 95^\circ\text{F}$) and (b) number of days in heatwaves, the current decade is experiencing no more than was experienced 100 years ago. For example, in the 30-year period 1925–1954, representing only 23% of the 1899–2024 data record, the

CONUS experienced 33% of the total heat wave days. The most recent 30-years experienced 24%, almost exactly that expected by chance. Thus, the NCA5 claim that "multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades," is seen to be simply false when expanding the temporal and spatial domains to encompass all available data (Ch6 Fig. 6.3.6 CWG25).

The NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG Section 8.6.1 discussed this event in detail, reviewing the findings of multiple peer-reviewed studies that explained the unusual meteorological conditions giving rise to it were unrelated to climate change, a point omitted from the NCA5 discussion.

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NCA5 finally turns to the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator ([\[HYPERLINK "https://www.globalchange.gov/indicators/heat-waves"\]](https://www.globalchange.gov/indicators/heat-waves)) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed this issue in CWG25 Section 6.3. The Figure referenced by NCA5 uses an *ad hoc* definition of heat wave, namely two consecutive days with minimum nighttime temperatures above the 85th percentile, and an *ad hoc* time scale which begins in the 1960s, the coldest decade in the last century, thus suppressing any comparison to the 1930s. Nighttime temperatures in urban areas have gone up faster than daytime temperatures (which the NCA5 acknowledges), but this is a signature of urban heat island effects and is not a good metric of climate change. CWG25 noted as well that the occurrence of hot days ($\geq 95^{\circ}\text{F}$) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

~details: NCA4 used entire 20th century while NCA5 looked at post-1960 interval

5 INADEQUATE TRACEABLE ACCOUNTS

Starting with the NCA3, the NCA has included a section on Traceable Accounts at the end of each Chapter. ~~A-This is the~~ description from the NCA5:

"Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team's expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources."

The Traceable Accounts for each Chapter and Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts are in principle an important factor in addressing the NCA's statutory requirement to discuss scientific uncertainties. Further, the Traceable Accounts can help satisfy the Executive Order for Restoring Gold Standard Science with regards to: reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the execution of the Traceable Accounts is uneven, often superficial and noninformative in Chapters 2 and 3 (which were the only Chapters investigated here). ~~Here is An~~ example from Chapter 2:

Key Message 2.2: Extreme Events are Becoming More Frequent and Severe.

Description of the Evidence Base consists of two paragraphs, with the first paragraph summarizing the findings and the second paragraph providing a generic description of the types of data that can be used for storms. Major Uncertainties and Research Gaps focuses on the uneven distribution across US populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning, and the lack of homogenized daily and hourly temperature data except from reanalysis products.

The most astonishing deficiency is in the Description of Confidence and Likelihood. One of the statements in Key Message 2.2 is: "Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence)." The Description of Confidence and Likelihood includes the following statement: "Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher." No reference to journal publications or a specific data set is made in the Chapter regarding hurricane induced precipitation or storm surge to support this *high confidence* conclusion.

With regards to Chapter 3, there are some substantial inconsistencies between the Traceable Accounts for the different Key Findings:

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Key Message 3-1: Human activities have caused global warming.

Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

The Uncertainties section only addresses uncertainties in radiative forcing of greenhouse gases.

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By contrast, consider Key Message 3-4: Humans are changing Earth System processes. The Traceability Analysis in this section contains arguably the most scientifically credible text in the entire Chapter. From Description of Evidence Base: "In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals". From Major Uncertainties and Research Gaps: "For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability."

As part of the Traceable Account: "Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation." "Upon clicking on the eyeball icon above a particular figure, a Contact US email appears, addressed to the USGCRP. No attempt was made to send a email to elicit the Metadata information, but it is clear that this information is not readily accessible online.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.

5 OVERCONFIDENCE WHEN STATING CONCLUSIONS

~details

6 RELIANCE OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to “project major trends for the subsequent 25 to 100 years,” the NCA relies on projections of future climate change are based on driven by estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.” In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. NCA5 makes the following statements observations about future the scenarios they use:

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“NCA5 authors were advised to assess the full range of scenarios available.” (Front Matter)

“Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency.” (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue The the NCA5 otherwise ignored a the problem large body of literature (summarized in section xxx of the DOE Report) that shows the 8.5 and the 7.0 scenarios to be implausible, and advises against using them for policy making purposes. In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.”

Even in the context of NCA5 being advised to assess the full range of scenarios available, aA keyword search of the NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, 10 figures only included the 8.5 scenarios: 5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13.

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The problem of relying on extreme scenarios is particularly is extreme acute for NCA5’s sea level rise projections. The sea level rise scenarios used in the NCA5 do not relate directly to the SSP emissions scenarios, but to specified amounts of sea level rise by 2100, whereby Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet). (Table 4 of Guide to Using this Report).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5

Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters) relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 50 years (2020–2070), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2012¹¹

Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.66 (2.7)	1.12 (0.34)	4.92 (1.5)	8.66 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

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Considering only projections representing processes in whose quantification there is at least medium confidence, the IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m for the 5th–95th percentile range), for all scenarios ranging from RCP2.6 to RCP8.5. The IPCC AR6 cites values as high as 2.4 m at the upper end of the 95th percentile range for RCP8.5. If estimates include the hypothesized Marine Ice Cliff Instability (low confidence), the corresponding

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Nevertheless, the range of sea level rise scenarios considered by the NCA5 includes intermediate-High (1.5 m) and High (extends to 2.0 m) values that associated with the implausible extreme emissions scenario RCP8.5 and processes in which there is low confidence in understanding. Further, the NCA5 neglects to include plausible lower scenarios, such as 0.2 m cited by the IPCC, that which also corresponds to the average rate of sea level rise over the past century.

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With regards to actual predictions of sea level rise, Chapter 9 of the NCA states: "Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2)." These values of sea level rise encompass the Intermediate scenario to values slightly higher than the High scenario from Table 4. << which Table 4?

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Global sea level rise projections to 2050 relative to a 2000 baseline can be evaluated with respect to the observed global sea level rise from 2000–2024, which is approximately 3.39 inches (0.28 feet).

[HYPERLINK "https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level"]

Hence it is inferred that NCA5 is projecting values of sea level rise between 2025 and 2050 that are 3.5 to 5.8 times the rate observed during 2000–2024.

Chapter 9 further states: "Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9–13 inches." This analysis accounts for the observed sea level rise between 2000 and 2020.

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With regards to confidence levels, NCA5 Chapter 9 Traceable Accounts states: "There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050" Neither the statement nor the context in the paragraph does not distinguish as to whether this refers to global sea level rise, or US average sea level rise, although it is inferred to refer to global sea level rise.

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In summary, the NCA5 presents future sea level rise scenarios that are not directly relatable either to SSP/RCP emissions scenarios or global Global warming Warming levels Levels. The NCA5 scenarios include some two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and that include hypothesized ice sheet processes for which there is low confidence. Projections to 2050 require rates of sea level rise during from 2025 through to 2050 that are more than three times the rate observed during 2020-2024. Further, the NCA5 ascribes *high confidence* to these sea level rise projections.

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The In summary, the NCA5 inclusion, and even the focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 BIASED SELECTION OF REFERENCES

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8 SUMMARY: EVALUATING ~~EVALUATION~~ OF THE NCA5

8.1 Inadequate NASEM Review

The NASEM Review failed to raise any of these ~~the~~ issues ~~we have discussed herein~~. Much of it focused on social and policy issues (e.g., Comments on Equity and Justice), rather than on the underlying science. In our assessment NASEM failed to apply the serious rigor one would expect. A few extracted comments from it will illustrate. Note that NASEM review comments are included here in blue font for reference. NASEM praised ~~the section Chapter 2 as a whole by~~, saying:

The chapter [2] meets the requirements of Section 106 of the GCRA.

Yet contrary to the requirements of Section 106 the NCA5 did not discuss natural variability let alone assess the full climate record available for quantifying natural variability. Chapter 2 actually minimizes natural variability by claiming (unsubstantiated) skill in attributing recent extremes to human causes. For example NCA5's Chapter 2 Introduction states,

"...recent advances in attribution science (KM [[HYPERLINK "https://nca2023.globalchange.gov/chapter/3"](https://nca2023.globalchange.gov/chapter/3) \l "key-message-3" \t "_blank"]) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."

CWG25 reviews the expert literature demonstrating that this particular event would have happened with or without climate change and that for the CONUS, hot extremes are no more frequent now than they were in the past. NASEM did not challenge the unsubstantiated attribution claims in the NCA5.

Notwithstanding NASEM's claim that the ~~section Chapter~~ complies with Section 106 of the GCRA it then acknowledged the absence of discussion of natural variability:

...the discussion and references regarding the role of natural climate variability and its regional differences are missing.

While a nod to natural variability is occasionally found in NCA5, it is usually followed by a "however" to emphasize human influence. One example is the statement just before the claim mentioned above pertaining to extreme event attribution: "There has always been extreme weather, which occurs even in an unchanged climate due to the natural variability of the Earth system. However, recent advances in attribution science (KM [[HYPERLINK "https://nca2023.globalchange.gov/chapter/3"](https://nca2023.globalchange.gov/chapter/3) \l "key-message-3" \t "_blank"]) mean that the role of climate change in some extreme events can now be quantified in real time..."

We pointed out that the evidence regarding heatwaves directly contradicts Key Message 2.2. NASEM did not mention this, instead it focused on a somewhat esoteric issue of terminology:

"Extreme Events Are Becoming More Frequent and Severe."

Key Message 2.2 is another generally well written key message. However, while the title of this key message includes the word "risk," the key message is exclusively about hazard. The Committee suggests rewriting the key message title to more accurately reflect the discussion on hazards.

The NASEM review appears to accept the NCA5's use of short data records because it makes no critical remarks about the failure to assess long time series, except for its observation that the use of short records makes the omission of natural variability that much more of a problem:

It is also important to point out that the influence of natural climate variability becomes particularly strong when the climate trend is computed based on short periods of time or small geographic areas.

This comment was largely ignored in the NCA5 final text.

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8.18.2 Pertinent aspects when evaluating NCA5 in light of statutory requirements

- not our remit to make a ruling but here are aspects to consider in light of statutory requirements

8.28.3 Evaluation from the perspective of expert users of the report

- we have deep knowledge of the topics surveyed by the NCA5 authors
- we do not have confidence that the report was balanced and comprehensive
- we can point to many specific instances in which the report did not exhibit an appropriate level of quality or integrity as a scientific document
- we have reason to believe the whole process, from author selection to handling of expert reviews, was biased towards reinforcing foregone conclusions and alarmist messaging

8.38.4 Evaluation from the perspective of citizens interested in good policymaking

- Public concerns about climate change are valid, as are concerns about cost of living, economic growth, employment, etc.
- We share the general concern that elected officials and those who serve them have the best information available when making important decisions around energy and climate policy
- NCA5 was a missed opportunity: it could have been a valuable input to that process but it did not turn out that way
- consequently its usage is unlikely to lead to better decisions and would more likely increase the error rate in policy formation and we recommend it not be used for policymaking purposes.

APPENDIXES

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APPENDIX 1: Seth's letter on statutory requirements for NCA5

APPENDIX 2: Analysis of 141 U.S. Longterm Daily Precipitation Records.

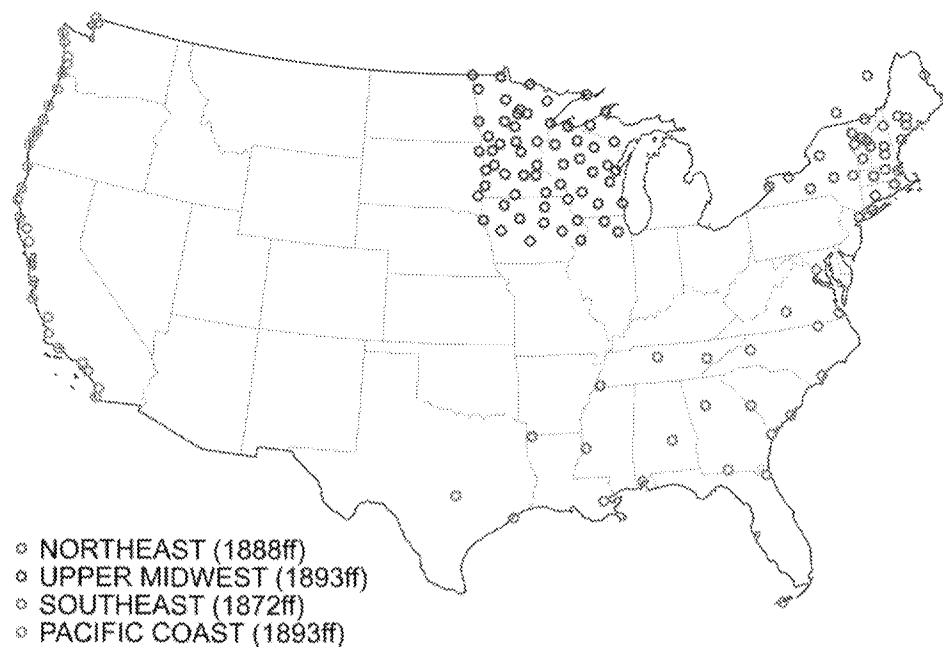


Figure. Stations used in the following analyses.

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure

Column 2: Number of stations in that region

Column 3: Count of stations exhibiting a significant positive trend

Column 3: Count of stations exhibiting a significant negative trend

Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)

Number of 99 th pct exceedances	29	1	0	(-)
--	----	---	---	-----

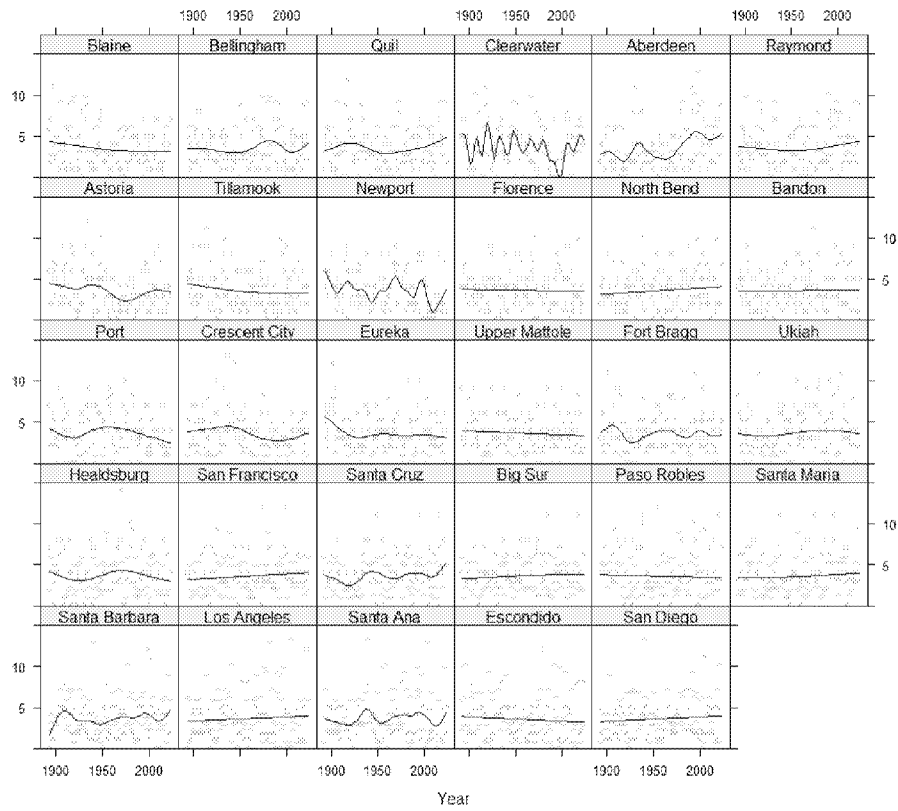
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

Annual No. 99th Percentile Exceedances PC 1893-2024



SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

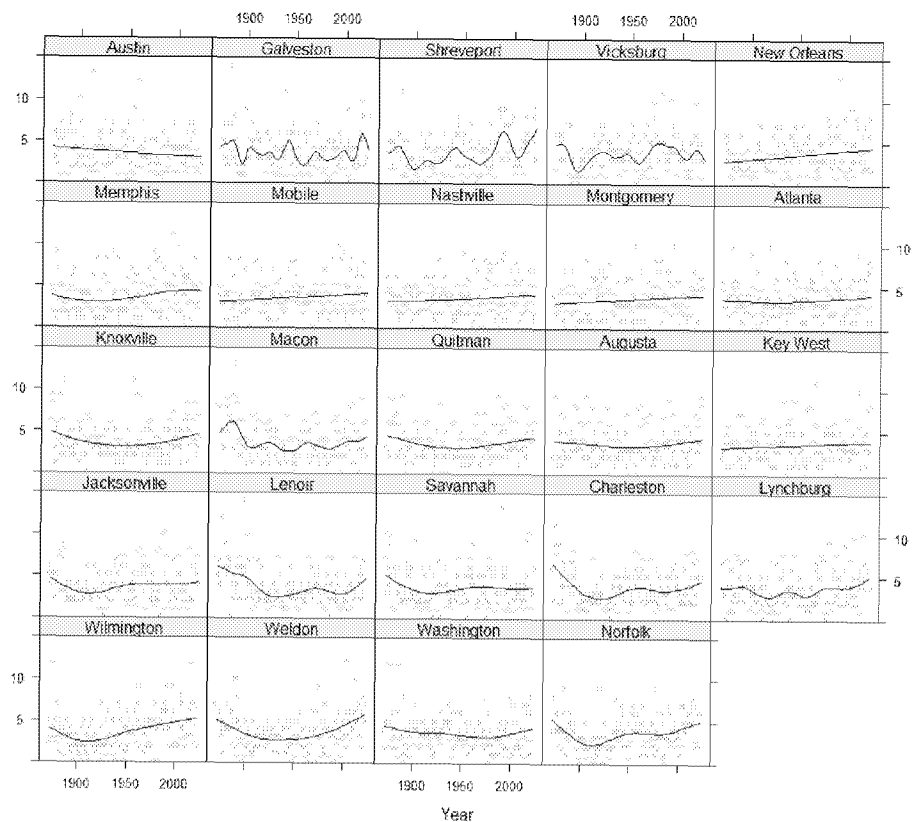
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

Annual No. 99th Percentile Exceedances SE 1873-2024



MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

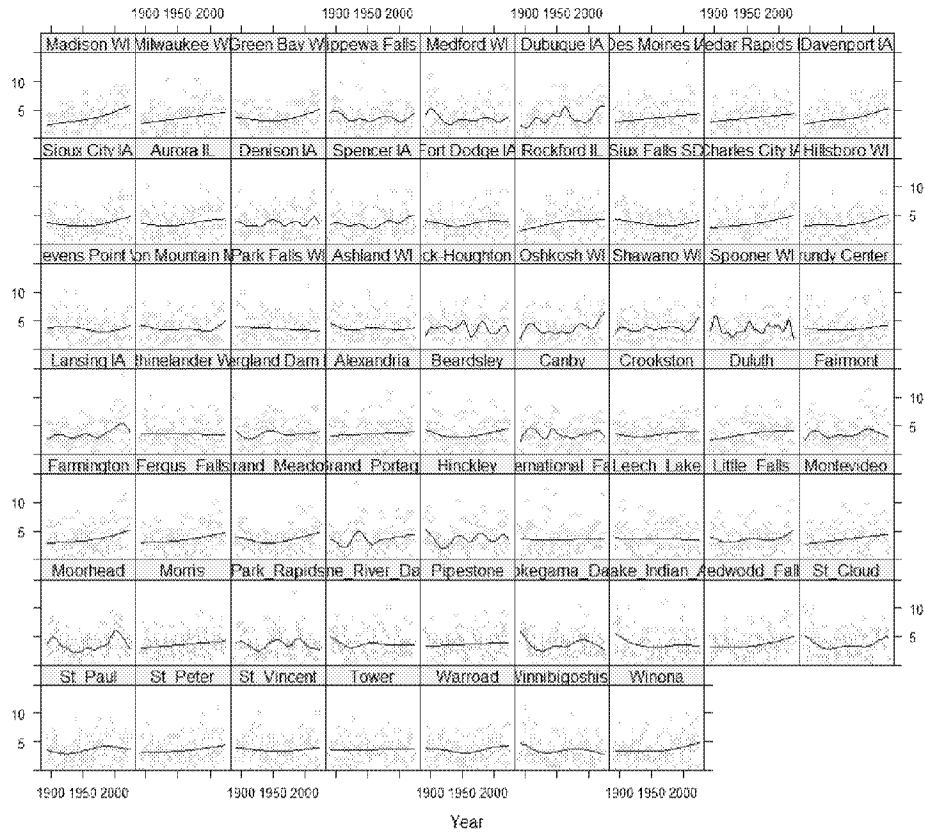
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

Annual No. 99th Percentile Exceedances MW 1893-2024



NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

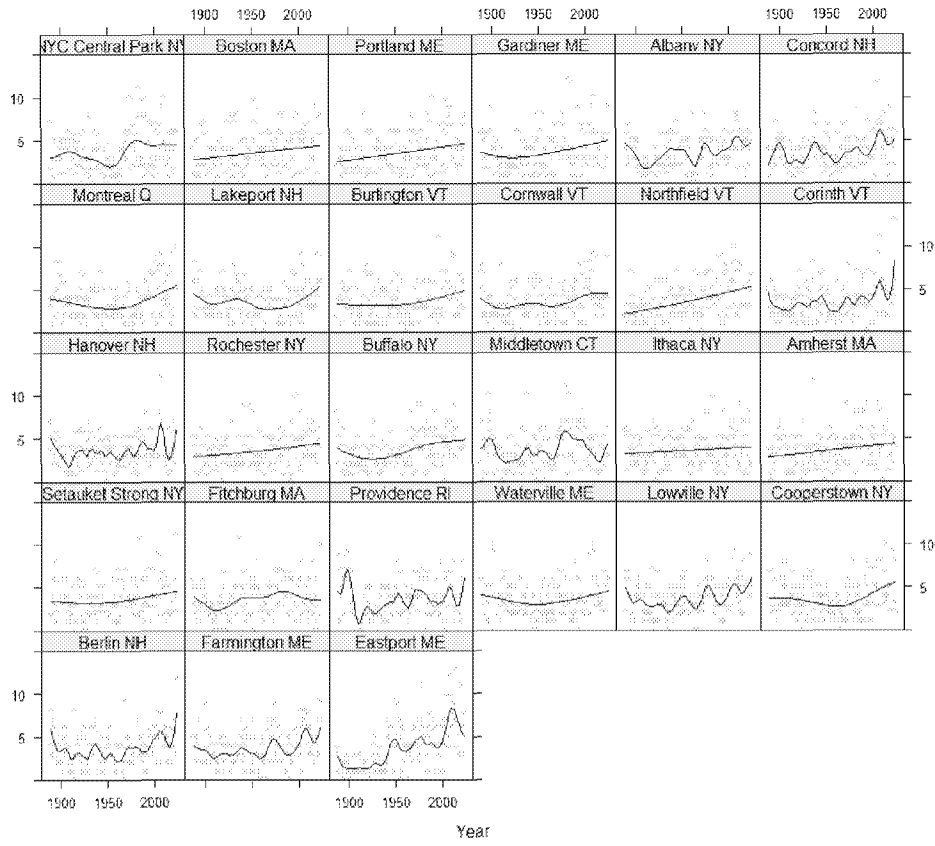
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

Annual No. 99th Percentile Exceedances NE 1888-2024



Review of the Fifth National Climate Assessment

[TOC \O "1-3" \H \Z \U]

1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix XX) that we assess the suitability of the Fifth National Climate Assessment for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, NASEM review of the Third Order Draft and the USGCRP responses to the review. We have drawn upon our long experience working on advisory reports, including for the NASEM, IPCC and other organizations, as writers, reviewers and project leaders.

~~Our report begins with background on the National Climate Assessments. We then discuss the standards by which we have assessed NCA5, followed by specific deficiencies that we have identified~~

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of the science as of its publication date in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted "CWG25"). The overall effect of ~~its~~ the biases and omissions of NCA5 is an excessively dire picture of climate risk.

~~Our report begins with background on the National Climate Assessments. We then discuss the standards by which we have assessed NCA5, followed by specific deficiencies that we have... we've identified.~~

1.2 About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.

- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change, but also sought to identify potential adaptation measures and identify the highest priorities for future research.
- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was an expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science. NCA4 introduced a traceability analysis for each key finding, including a cursory description of uncertainties.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on "Climate Action" and policy recommendations with a social justice emphasis. NCA5's self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA's statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (~~see the Box nearby for an example~~). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

~~Good climate and energy policies will balance the risks and benefits of a changing climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics—the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects are the only people who can bring the facts to the discussion and so have a unique responsibility to communicate their understanding to non-experts clearly, completely, and without bias.~~

~~Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.~~

~~Because climate is at the core of human existence, it can engender passion and emotion. Indeed, some younger climate scientists have gone into the field to "save the planet." So it isn't surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. When that happens, it This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.~~

Philip Handler, President of the National Academy of Sciences, identified the problem in a 1980 [HYPERLINK "<https://science.sciencemag.org/content/208/4448/1093>"] that resonates eerily four decades later:

~~Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.~~

In Appendix XX we include a letter of guidance from the Office of General Counsel, U.S. Department of Energy, summarizing the extent of statutory requirements governing USGCRP work products in general and NCA products in particular.

We can summarize the standards applicable to the NCA as follows:
- details.

Beyond the statutory requirements we draw attention to two other pertinent standards. President Trump's executive order of May 23, 2025, "[HYPERLINK "<https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/>"]" enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some have found them [HYPERLINK "<https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science>"].

~~Finally, we consider that when scientific reports are being assembled that will be highly influential on climate policymaking there are other desiderata, including statements about the strength of climate knowledge. The IPCC's approach is based on judgment of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include: REFERENCE AVEN. SAVE THE DETAILS FOR SUBSEQUENT SECTIONS~~

- The degree to which the assumptions made are reasonable/realistic based on background knowledge—~~concern about the focus on implausible emissions scenarios RCP8.5/SSP5-8.5~~
- The degree to which data/information exists and are reliable and relevant—~~the historical and paleo database is inadequate for a complete characterization of natural climate variability on multi-decadal to millennial time scales~~

Commented [A1]: Terje Aven, "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices," Reliability Engineering & System Safety 167 (November 2017): 42–48

[HYPERLINK "<https://www.sciencedirect.com/science/article/pii/S0951832016306950>"]

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- The degree to which there is disagreement among experts (including those from different environments or academic fields)—attempts to suppress disagreement and alternative perspectives among experts
- The degree to which the phenomena involved are understood and accurate models exist—~~concerns about the fidelity and utility of climate models~~
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns and—~~neglect of the unknown knowns associated with natural climate variability~~

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Good climate and energy policies will balance the risks and benefits of a changing climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a unique responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.

Because climate is at the core of human existence, it can in recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to "save the planet." So it isn't not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem in a 1980 [HYPERLINK "https://science.sciencemag.org/content/208/4448/1093"] that resonates eerily four decades later:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

1.4 When Peer-Review Fails: An Example from NCA4

Peer-review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, NCA reviewers self-select on a volunteer basis whether to provide comments and what parts of the report to read, whereas in academic journals Editors recruit reviewers and assign them to specific papers. There is no guarantee that any particular section of an NCA report was reviewed by anyone, let alone by someone with a different perspective than the authors. This is a problem with NCA and IPCC reports since over the years many potential reviewers have given up making the effort, because their input has systematically been ignored. Second, and

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related, NCA authors have near complete authority whether to accept or reject review comments. Here, for example, is how a review comment critical of a section of the NCA5 draft was handled by the authors:

THIS IS A VERY SKIMPY EXAMPLE. The comment doesn't cite any specific statement that he is complaining about.

CITE THE STATEMENT IN NCA5 TO WHICH PIELKE COMPLAINED ABOUT. ALSO CITE HIS NEW PAPER DESCRIBING THE PROBLEMS WITH HIS CITED DATA SET.

[HYPERLINK "<https://journals.ametsoc.org/view/journals/apme/64/4/JAMC-D-24-0222.1.xml>" \t "_blank"]

REVIEWER COMMENT

Tropical Cyclones/hurricanes have not increased (Klotzbach, P.J., Bowen, S.G., Pielke, R. and Bell, M., 2018. Continental US hurricane landfall frequency and associated damage: Observations and future risks. Bulletin of the American Meteorological Society, 99(7), pp.1359-1376., Pielke, R., 2021. Economic Normalisation, A of disaster losses 1998, A 2020: A literature review and assessment. Environmental Hazards, 20(2), pp.93-111.)

US NCA RESPONSE

Thank you for your comment.

This comment is inconsistent with the author team's thorough assessment of the science.

By contrast in academic journals the Editor mandates the authors' to respond and the reviewer gets to assess its adequacy. ~~Third,~~ Once an NCA chapter author team has been selected publication of their work is guaranteed, whereas academic journals routinely reject papers if they do not pass review.

These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were "peer reviewed". But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a Figure that completely misrepresented the underlying data and which evaded peer review to do so. Further

START BOX

NCA4's Figure ES.5: A Tale of Deception and Review Failure

A disappointing example of NCA4's misrepresentation of climate science involves U.S. temperature extremes. Here is a summary of the issue; details can be found in Koonin (2024).

As we pointed out in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. ~~Taking~~ Considering cold and hot extremes together the U.S. the U.S. climate has become more moderate over time. NCA4's Part I (Climate Science Special Report, CCSR) says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:

Record Warm Daily Temperatures Are Occurring More Often

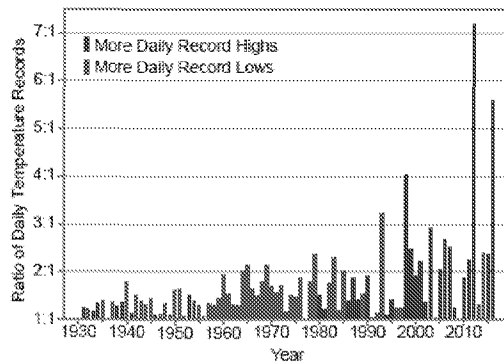
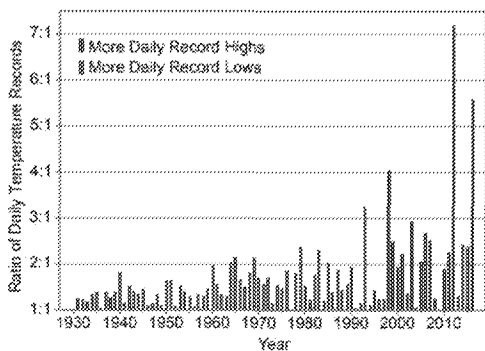


Figure ES.5: Observed changes in the occurrence of record-setting daily temperatures in the contiguous United States. Red bars indicate a year with more daily record highs than daily record lows, while blue bars indicate a year with more record lows than highs. The height of the bar indicates the ratio of record highs to lows (red) or of record lows to highs (blue). For example, a ratio of 2:1 for a blue bar means that there were twice as many record daily lows as daily record highs that year. (Figure source: NOAA/NCEI). From Figure 6.5 in Chapter 6.

Record Warm Daily Temperatures Are Occurring More Often



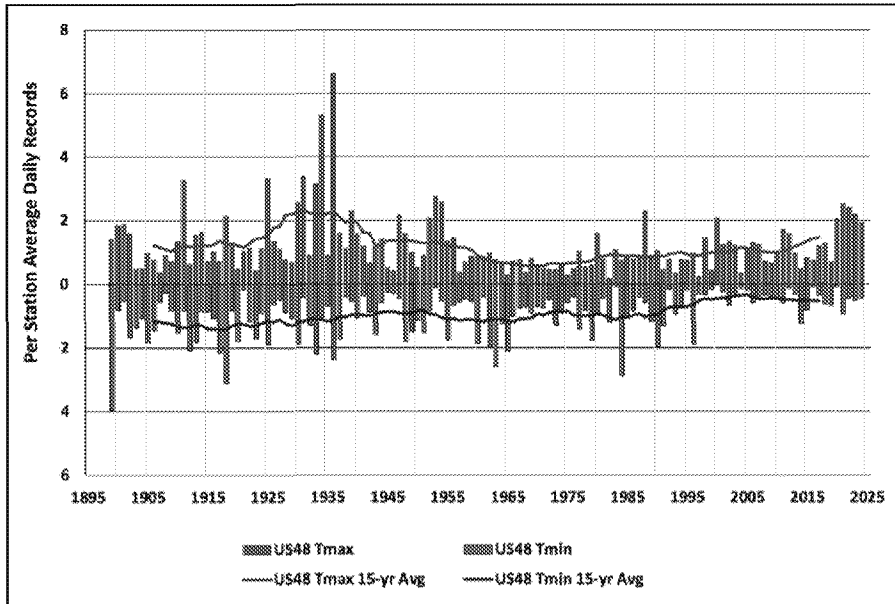
The Figure appears to validate the claim that, as the title says, record warm daily temperatures are occurring more often. But the underlying data do not; they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as NCA4 Figure 6.4 later shows. Figure ES.5 does

not show what its title implies: these are not simple counts of cold and warm extreme events; instead they are ratios of the two. In fact both types of extremes declined over the sample interval but cold events declined more than warm events, so the ratio of warm extremes to cold extremes went up increased. By graphing the ratio in this way the NCA4 created a visual impression opposite to what is in the data. CSSR Figure ES.5 The ratio of the number of daily record high temperatures to daily record low temperatures for many stations across the 48 contiguous states is shown for each year from 1930 to 2017. The lighter bars show a year in which there were more record highs than lows, while the darker bars show years in which there were more record lows than highs. The height of the bar indicates the ratio of record highs to record lows for each year. For example, a ratio of 2:1 for a dark bar means that the stations had twice as many record daily lows as record daily highs for that year. (CSSR, 2017)

Commented [A2]: Cite CSSR

Three idiosyncratic choices combine to generate the figure's seemingly alarming rise in recent decades. First, because the record extremes tallied are defined conventionally (i.e., each more extreme than any preceding value in the history), the numbers of record highs and record lows are both expected to decline through the years (it becomes increasingly unlikely that a record will be exceeded). Second, the graph displays not the numbers of record highs and lows, but rather their ratio. And finally, the history begins only in 1930 when, in fact, data exist beginning in the late 19th Century. The upshot of these choices is that the resultant figure is guaranteed to show a long period of quiescence around followed by dramatic variations, creating the impression of large changes in recent decades, even if they aren't present.

Figure 6.3.3 of our report CWG25 (reproduced below) shows the results of a proper analysis of the data – defining each record as the singular extreme in the history, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. On the cold side, the Valentine's Day Arctic outbreak in Feb 1899 stands as the most extensive cold extreme experienced by CONUS, with 1917 in 2nd place. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the extreme Tmax records were achieved in the last quarter, in accordance which is consistent with statistical expectations. As a result, the ratio of heat to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. And the overall reduction in numbers of both cold and hot extremes over the past century indicates a climate less prone to extremes, in sharp contrast to the title of the CSSR figure, "Record Warm Daily Temperatures Are Occurring More Often" the message of the NCA4 Figure ES.5.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3. DON'T BOLD THE CAPTION

The National Academies' expert review panel [[HYPERLINK "https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report"](https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report)] the discussion of temperature extremes in a [[HYPERLINK "https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf"](https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf)] of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) [[HYPERLINK "https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf"](https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf)] to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The “new figure” referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies’ panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn’t have survived to publication. And the figure’s problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

While the following statement has far less headline potential than that from the CSSR’s page 19 quoted at the beginning of this box, it has advantage of being correct:

~~There have been some changes in temperature extremes across the contiguous United States. The annual number of high temperature records set shows no significant trend over the past century nor over the past 40 years, but the annual number of record cold nights has declined by a factor of 4 since 1895, somewhat more rapidly in the past 30 years.~~

Commented [A3]: Check this statement

Commented [A4R3]: R^2 is 0.02, so not significant for 1978-2017.

END BOX

With this background we now present our critique of NCA5.

2 NCAS OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND NON-SCIENTIFIC TONE

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The NCAS opening Chapter 1 "Overview" holds a prominent place in the Report since it serves as a summary of the whole report and is the only section that many will read. While the later Chapters of NCAS contain much sound scholarly content, in the later sections of NCAS Chapter 1 is marred by a pervasive tone and language that aggressively uses advocacy language and a tone overly focused on promoting aggressive emission reduction policies. The authors must have known this chapter would be mined for quotes by the media and activists looking to. As such, this chapter adds an imprimatur of scientific authority to oversimplified declarations of opinion about public policy. Many examples can be cited; here we provide a few examples that are particularly egregious ones.

The chapter Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic in origin, all warming is bad and causes economic damage, warming causes extreme weather to intensify. Such sweeping generalizations go well beyond what science has or can establish. A scientifically-sound version of this paragraph would instead say something like the following:

Commented [SK5]: There's also no quantification. Perhaps risks increase, but how big were they to begin with?

The Earth is undergoing a warming trend caused by a combination of natural and anthropogenic influences. This warming can be expected to will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. There is evidence that some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases may slow the warming process although such policies have proven to be very expensive costly and disruptive, so the costs need any climate actions to be weighed against the potential benefits.

On the next page the Overview goes on to say:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits..."

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads

to economic harms, indeed (as is acknowledged in Chapter 19 on Economics) in some cases it is expected to yield benefits there will be benefits. Nor is climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers, not to be honest about this.

Page 9 promotes renewable energy options by arguing not, correctly, that the “levelized” costs of wind- and solar power generation have fallen sharply since 2010. But “levelized” refers to the lifetime project cost averaged over all power production and ignores the intermittency problem: namely solar and wind are not always available. It results in an invalid comparison since even if, for instance, the levelized cost of solar energy per megawatt-hour falls below that of coal, coal power is available continuously and on demand whereas solar is not. The proper comparison would adjust for the difference in availability by considering the cost of supplementing solar and wind with backup natural gas-fired systems or battery storage, and on that basis renewable energy remains prohibitively expensive. Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) more than doubles the cost substantially increase the cost of electricity. Further, there are yet unmet synchronization challenges in transmission grids with heavy penetration of wind and solar power, wind/solar-heavy grids. Here again it is a disservice to readers, advisory malpractice not to acknowledge these facts.

Page 14 presents future emission scenarios with the following description: “Climate modeling experts develop global climate projections for a range of plausible futures.” The word “plausible” is applied to all the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The figure does not contrast observed emissions against model previous projections nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as “plausible” the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline “business-as-usual” future.

Commented [SK6]: Perhaps we should cite the relevant text from NCA5 Box 1.1 (pg 1-8): Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources (Figures 1.2, 1.3), (5.3, 12.3, 32.1, 32.2; Figure A4.17)

Commented [SK7]: Didn't AR6 WG1 deem 7.0 and 8.5 scenarios “low likelihood”?

[We could criticize Figure 1.6, which uses an anecdote to support its 1200 claim.]

Page 17 (and elsewhere) invokes the NOAA Billion Dollar Dataset as an indicator of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product. Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends.

Commented [SK8]: They actually say this, sort of, on pg 1-17, but don't make the effort to untangle hazard vs risk, and go on to blame it all on climate change

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Page 23 states, in large font:

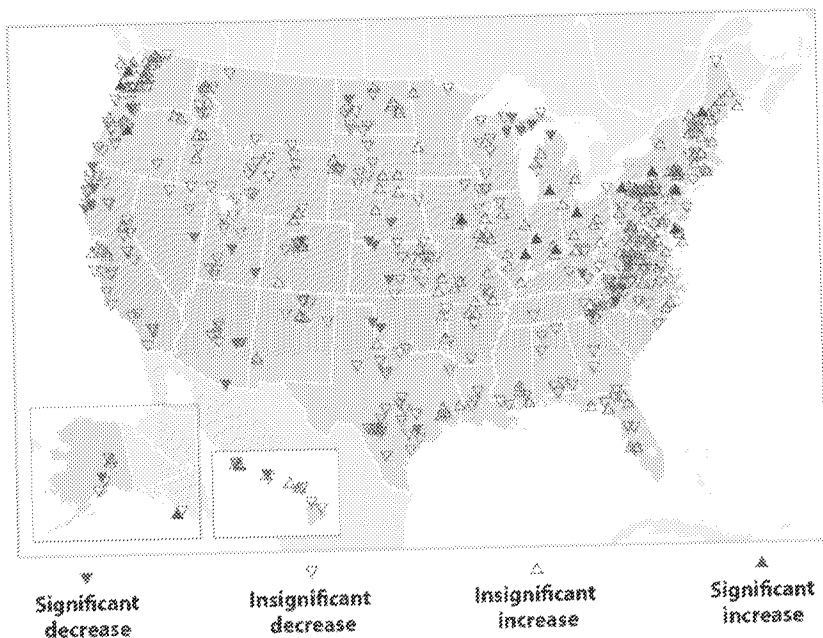
Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

Commented [SK9]: Some climate changes are benign or even beneficial.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote hysteria, but also the ineffectiveness of the review process at not ensuring such statements are removed.

~~DELETE THE FLOOD EXAMPLE. MUCH WEAKER THAN THE OTHERS THAT ARE FOCUSED ON POLICY AND ADVOCACY~~

We won't try to cite all the remaining examples of advocacy and hyperbole in the Overview chapter; one more example will suffice. Page 26 states "Increasing flooding puts more people and assets at risk." The accompanying figure contrasts model-projected flood losses by county in 2050 to that observed in 2020 as estimated in Wing *et al.* (2022)¹. Hence the evidence for the claim is not currently observed trends, ~~rather~~ it is a model-generated projection of changes. But current trends in U.S.-based flooding reveal a more complex picture with a general overall trend towards less flooding. The Environmental Protection Agency's "Climate Change Indicators: River Flooding" webpage² shows maps both of flood magnitude and frequency. Both show more regions experiencing declines over 1965-2015 than increases. Hence current trends indicate generally declining U.S. flood risks, but the NCA5 Overview not only fails to mention this but declares the opposite based on a single study presenting model-generated forecasts of flood activity decades in the future.



U.S. Flood magnitude trends 1965-2015.

Source: [HYPERLINK "<https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding>"]

¹ Wing, Oliver, William Lehman, Paul Bates *et al.* (2022) Inequitable patterns of US flood risk in the Anthropocene. *Nature Climate Change* 12 156–162 [HYPERLINK "<https://www.nature.com/articles/s41558-021-01265-6>"]

² [HYPERLINK "<https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding>"]

3 ONE-SIDED OVERSIMPLIFICATIONS IN SCIENCE SUMMARY CHAPTERS OVERCONFIDENCE WHEN STATING CONCLUSIONS

Chapters 2 (Climate Trends) and 3 (Earth Systems Processes) form the scientific core of NCA5. As we will show in the following examples they fail to meet statutory requirements to discuss scientific uncertainties and the role of natural variability, and they fail to meet the more stringent implicit standards expected of a policymaking policy-informing report.

3.1 Inappropriate Certainty Grading ~~Inflated Certainty Levels~~

A general pattern in the NCA5 is overconfidence in stating conclusions. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

The NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of the NCA5 states that “confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.”

Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:-	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:-	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:-	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:-	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only ~~suggested~~ suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in the conclusions.

Even within the context of this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. Several illustrative examples are provided.

Key Message 3.1 Traceable Account states: “There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.” Compare the NCA5 ~~this~~ statement with statements from the IPCC AR5 and AR6:

AR5: "It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together." (IPCC, 2013)

AR6: "The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warmings since 1979." (IPCC, 2021)

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While the NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, the AR5 refers to "*more than half* of the observed warming" and the AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

NCA5 Key message 2.2:– "Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*)."

No justification is provided in Chapter 2 for the *high confidence* conclusion on higher storm surges or hurricanes causing heavier precipitation. The Traceable Accounts section, Description of Confidence and Likelihood states:—"Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have *high confidence* that storms are delivering more rainfall and high confidence that storm surges are becoming higher." In short, the NCA5 provides no observational basis or published research for their *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges; and does not meet its own standards for a *high confidence* level.

I WOULD DELETE THIS EXAMPLE. FIRST, THE NCA5 PRETTY MUCH PARROTS WHAT THE AR6 SAID, AND LEWIS WAS PROBABLY PUBLISHED AFTER NCA5 LITERATURE CUTOFF. THE SENSITIVITY STUFF IS GOOD FOR THE CWG REPORT, BUT NOT FOR NCA ASSESSMENT

~~3.2 Range of Increased Lower Bound of Climate Sensitivity~~

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The promotional tone of Chapter 1 is carried forward into Chapter 3 (Earth System Processes) where states, on page 3-10, Key Message 3.2, states "The Estimated Range of Climate Sensitivity Has Narrowed by 50%". Referring to Equilibrium Climate Sensitivity (ECS) the section elaborates:

Recent improvements in the understanding of how climate feedbacks vary across timescales have narrowed the estimated *likely* range of warming expected from a doubling of atmospheric carbon dioxide by 50% to between 4.5°F and 7.2°F (*high confidence*). This uncertainty reduction results from advances in combining observations and targeted modeling results from nearly independent lines of evidence, each of which generally agrees on the values of ECS. The lines of evidence include 1) observed present-day variations on monthly to interannual timescales from which cloud and other climate feedbacks are inferred; 2) observed temperature changes between the preindustrial period and present and associated relationships to ERF; and 3) estimated temperature and radiative forcing changes for multiple warm and cold periods in paleoclimate records.

The graphic summary on page 3-11 states

The reduced uncertainty in climate sensitivity and climate feedback has been achieved through unprecedented quantitative synthesis of evidence from observed changes over recent decades, the industrial era, and paleoclimate.

This is a ~~very grossly inadequate~~ description of the situation. The key development in AR6 was a ~~reduction of confidence in the ability of climate models to identify ECS and the shift away from the model-based method the IPCC had relied on since AR1 in 1990.~~ The IPCC instead turned to data-driven ECS estimation and specifically chose a single paper from the scientific literature, Sherwood *et al.* (2020³) for the purpose. It combined paleoclimate data, modern instrumental data and modern observations of climate processes, mainly cloud-related, that govern key feedbacks. Sherwood *et al.* used a subjective Bayesian method to determine the likely range of ECS values. The Bayesian approach begins with the researcher specifying a “prior”, namely an expectation of ~~the likely distribution of what the answers will be before seeing the data.~~ In this case the prior consists of an expected ECS range based on the researchers’ subjective beliefs. Then the data are allowed to influence the ECS distribution and the final result is a weighted average of the assumed prior and the data-driven result. Sherwood *et al.* found a best (or median) ECS estimate of 5.4°F (3°C), which was close to previous model-based estimates but raised the likely lower bound by 1.7°F from 2.5°F to 4.2°F. The IPCC accepted this result and increased the best estimate to 3.1°C.

The NCA5 was published in November 2023. Well before that, in September 2022, Lewis (2023) had been published online at *Climate Dynamics* presenting a forceful critique of Sherwood *et al.*⁴ One of Lewis’ points was that Sherwood *et al.*’s result was dependent on their chosen subjective prior. Lewis recommended using an objective Bayesian method, which places primary weight on the data rather than the researcher’s expectation. Using that and updated forcing data from AR6, Lewis estimated an ECS best estimate of 3.74°F (2.2°C) with a likely lower bound of 2.97°F (1.6°C).

Hence, in contrast to the promotional language of Chapter 3 a more valid summary of the ECS literature as it stood at the time of writing the NCA5 would be what we wrote in CWG25 (emphasis added):

For the AR6, the IPCC placed primary weight on the results of Sherwood *et al.* (2020) that combined historical and paleoclimate proxies with the process-based approach and yielded a best estimate of 3.1°C with a *likely* range of 2.6–3.9°C. Lewis (2022) raised a number of concerns about this result, including methodological errors, outdated input values, and use of subjective versus objective Bayesian priors in the analysis. Lewis’ analysis found that climate sensitivity is estimated to be much lower and better constrained than in the Sherwood *et al.* analysis—median 2.2°C (1.8–2.7°C in the 17–83 percent *likely* range, and 1.6–3.2°C in the 5–95 percent *very likely* range). **The IPCC AR6 estimated only a 5 percent probability that ECS was below 2.3°C, whereas Lewis estimated it to be over 50 percent.**

³ Sherwood, S. C., Bony, S., Boucher, O., Bretherton, C. S., Forster, P. M., Gregory, J. M., & Stevens, B. (2020). An assessment of Earth’s climate sensitivity using multiple lines of evidence. *Reviews of Geophysics*, 58(4). [HYPERLINK “https://doi.org/10.1029/2019rg000678”]

⁴ Lewis, N. (2023). Objectively combining climate sensitivity evidence. *Climate Dynamics*, 61(9–10), 3155–3163. [HYPERLINK “https://doi.org/10.1007/s00382-022-06398-8”]. The final citation for this paper is Lewis (2023) because the print edition did not appear until 2023, but the article was accepted in August 2022 and the online edition appeared and was in circulation in September 2022.

The most recent publications on the debate between Sherwood *et al.* and Lewis further defend their respective positions: Sherwood and Foster (2024) and Lewis (2025).

~~I WOULD DELETE THIS EXAMPLE. WE HAVE ANOTHER MORE EFFECTIVE SECTION ON EMPHASIS ON EXTREME EMISSIONS SCENARIOS~~

~~3.3 Presenting New Emission Scenarios as a Scientific “Advance”~~

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Chapter 3 pp. 13-14 treats the release of new emission scenarios as a scientific “advance” without addressing the failure of many previous scenarios to match reality or providing an honest assessment of the likelihood that the new ones are ~~remain~~ biased in the same way.

Key Message 3.3 states “New Data and Analysis Methods Have Advanced Climate Science” and includes the following:

New scenarios of socioeconomic development, and their associated emissions and land-use changes, drive updated climate projections from Earth system models. The Scenario Model Intercomparison Project (ScenarioMIP) organized the main set of 21st-century projection experiments under the latest phase of the Coupled Model Intercomparison Project, CMIP6. These CMIP6 projections used newly developed scenarios based on Shared Socioeconomic Pathways (SSPs; Figure 3.4). Five SSPs represent alternative plausible trajectories of 21st-century GDP and population growth and the pace and pervasiveness of socioeconomic and technological progress within individual nations and across the world (see Table 3 in the Guide to the Report). SSP-specific drivers are used in integrated assessment models (IAMs) to simulate the corresponding evolution of the energy system and the resulting greenhouse gas trajectories. These are in turn used by ESMs to drive their 21st-century projections.

There is nothing wrong with NCA5 discussing the development of new emission scenarios which serve as inputs to climate change projections and impact studies. But it is a serious omission not to inform the reader of the failure of many previous IPCC scenarios to match reality and the tendency of the scenario groups to exaggerate near-term and long-term CO₂ concentration growth (CWG25 3.2.1). It is also a serious omission not to caution readers that many climate impact studies use RCP8.5 which by the time of NCA5 had already been heavily criticized in the literature.

The same section also reports the availability of new and larger model ensembles as a scientific advance, without addressing ways in which models are getting worse in some key respects (CWG Ch 5).

~~DELETE THIS SECTION. IT IS AN OBSCURE TOPIC AND DOESN'T OBVIOUSLY FIT IN THE OVERCONFIDENCE SECTION~~

~~3.4 Uncritical Promotion of “Emergent Constraints” and uncertainty in climate projections~~

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Chapter 3 page 17 presents the topic of “emergent constraints” in uncritical terms:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as "emergent constraints." The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as a way to tie GCM behavior to climate observations in hopes of generating insight into real-world ECS. Climate models exhibit a wide range of sensitivities. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could check if the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a large proliferation of proposed correlations with little physical motivation. Many emergent constraints patterned on CMIP5 models failed to work on CMIP6 models (Schlund *et al.* 2020)⁵. In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the Earth climate system. The result was that emergent constraints estimated on CMIP5 models widened the range of estimated ECS values when applied to CMIP6 models.

Schlund *et al.* summarized the problem as follows:

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great "advance" that reduced uncertainty.

~~DELETE THIS EXAMPLE. THE IMPORTANT PART OF THIS EXAMPLE IS ALREADY IN SECTION 3.1~~

~~3.5 Increasing hurricane intensity~~

NCA5 Key message 2.2 states

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⁵ Schlund, Manuel, Axel Lauer, Pierre Gentine, Steven C. Sherwood, and Veronika Eyring (2020) Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6? *Earth System Dynamics* 11 1233-1258 [[HYPERLINK "https://doi.org/10.5194/esd-11-1233-2020"](https://doi.org/10.5194/esd-11-1233-2020)]

~~"Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*)."~~

No justification is provided in Chapter 2 for the *high confidence* conclusion on higher storm surges or hurricanes causing heavier precipitation. The Traceable Accounts section, Description of Confidence and Likelihood states:

~~"Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes; this is why the authors also have *high confidence* that storms are delivering more rainfall and high confidence that storm surges are becoming higher."~~

In short, the NCA5 provides no observational basis or published research for their *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges; and does not meet its own standards for a *high confidence level*.

3.6 Overstating Findings findings in Underlying underlying Sourcesources

3.5 THIS ONE WORKS IN THE OVERCONFIDENCE CHAPTER, BUT THE EXAMPLES ARE NOT WELL DESCRIBED

Although we did not do a detailed audit of the NCA5's use of source material, a few spot checks turned up evidence of a pattern of overstatement.

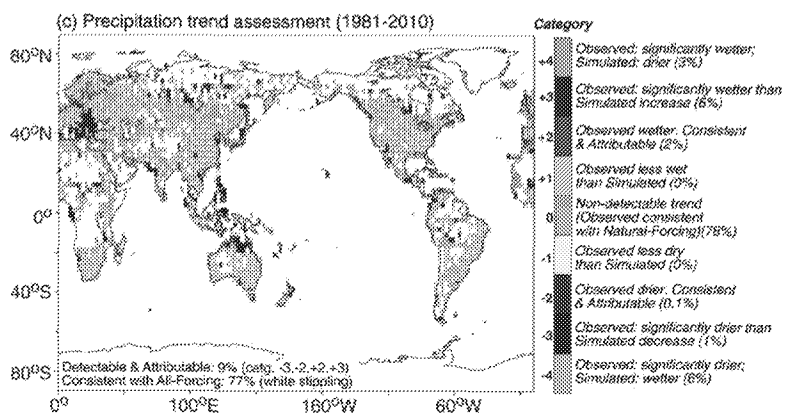
Chapter 2 page 11 reports on an increase in precipitation in central and eastern US based on a comparison of 2002-2021 average rainfall to the average over 1901-1960. Note that this a non-standard metric; we will discuss NCA5's inconsistent choices of time scales of analysis below. The change in this case is called a "trend" even though this is not how a trend is measured, and says that it is "attributable to climate change". The claims were attributed to the following paper:

WOULD BE BETTER TO PROVIDE A DIRECT QUOTE FROM THENCA5

- Knutson, Thomas and Fanrong Zeng (2018) "Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends" *Journal of Climate* 31(12)
[HYPERLINK "<https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml>"]

But Knutson and Zeng did not say these things. It examined linear trends over 1901 – 2010, 1951 – 2010 and 1981 – 2010. It did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 – 1960, indeed it was published in 2018 so it could not have. With regard to 1981-2010 trends its results were summarized in the following figure:

DON'T NEED THE FIGURE. CAN YOU PROVIDE RELEVANT QUOTE FROM KNUTSON PAPER THAT IS AT ODDS WITH NCA5 CONCLUSION



Gray indicates no trends detected. Stippling means that there were no trends in the models either so the models and observations agreed in that respect. Detectable and attributable trends were found over only 9% of the land surface of the Earth. Over the US there are detectable trends over only a few regions in the Southwest.

Consider a 2nd example. NCA5, Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is attributed to two papers:

- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, **4** (2), 3354. [HYPERLINK "<https://doi.org/10.1126/sciadv.aao3354>"]

~~and~~

- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, **117** (24), 13308-13313. [HYPERLINK "<https://doi.org/10.1073/pnas.1921628117>"]

Diffenbaugh et al. presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not "robust" evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something which even the IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using 3 GCMs, found "A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically." However, they noted large differences among the three models in their simulated precipitation changes. Also, 2 of the 3 models failed to yield detection for Rx5Day for the North America mean. Finally, the authors used Total Least Squares, an estimation method known to overstate signal detection results (CWG Section 8.3.2). Here again this is not "robust" evidence, it is suggestive but other studies have found natural variability predominant. Both cited references utilized the implausible RCP8.5 scenario and began their "historical" observational records only in 1961.

4 RELIANCE ON *Ad Hoc* TIME SCALES FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need to be careful regarding the choice of time scale when making claims about trends in extreme weather. We gave examples from analysis of river flooding (6.1), heatwaves (6.3) and extreme precipitation (6.4) to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here we elaborate on these examples to illustrate a general point that NCA5 made inconsistent and *ad hoc* choices about time scales of analysis, weakening the validity of their conclusions.

McKittrick and Christy (2019)⁶ showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s depending on location or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017)).

In CWG Section 6.4 we presented analysis of updated data for the same locations and many more besides, in all cases finding considerable regional heterogeneity and lack of robustness of trends to use of long samples.

4.1 Average and Extreme Precipitation

McKittrick and Christy (2019)⁷ showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s depending on location or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017)).

In CWG Section 6.4 we presented analysis of updated data for the same locations and many more besides, in all cases finding considerable regional heterogeneity and lack of robustness of trends to use of long samples.

Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

“Rainfall is becoming more extreme”

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous U.S. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity. The largest increase in the number of extreme precipitation days (defined as the top 1% of heaviest precipitation events) has occurred over the Northeast (an increase of around 60%) and Midwest (around 45%), along with increases of more than 10% in their annual and 5-year maximum amount (Figure 2.8). These changes have contributed to increases in river and stream flooding in these regions. The increase in frequency and intensity of precipitation extremes is evident

⁶ McKittrick, R., and J.R. Christy (2019). Assessing changes in US regional precipitation on multiple time scales. *Journal of Hydrology*, 578, 124074. [HYPERLINK "<https://doi.org/10.1016/j.jhydrol.2019.124074>"]

⁷ McKittrick, R., and J.R. Christy (2019). Assessing changes in US regional precipitation on multiple time scales. *Journal of Hydrology*, 578, 124074. [HYPERLINK "<https://doi.org/10.1016/j.jhydrol.2019.124074>"]

across a broad range of event durations (from 1 to 30 days) and return intervals (1 to 20 years), particularly east of the Rocky Mountains.

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the U.S. Paleoclimate records derived from tree-ring growth provide evidence that summer moisture has increased over the past century in parts of New England, the central-eastern U.S. and the northern Mississippi River valley.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion, instead it refers to changes “since the 1950s” which we take to mean 1950 onwards though NCA5 Fig. 2.8 suggests 1952 as the start date. For the present report we have extended the analysis even further now to include 141 stations across the US in the Pacific Coast, Southwest, Midwest, Northeast and Southeast regions. We provide details in the Appendix; here we note merely that once again it is possible to find trends that support the NCA5 position, but they are not robust to selecting longer or shorter time scales of analysis. Data from 1950 to 2024 yields many indications of increased average and extreme precipitation at individual stations and region-wide averages. But when using the entire data set (back to the 1890s or earlier depending on location) or the later subset (1980 to 2024) the trends become smaller, in many cases they become statistically insignificant, and occasionally they change sign. Only in the Northeast region are the post-1950 trends robust to focusing on the post-1980 interval.

Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

“Rainfall is becoming more extreme”

~~Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity. The largest increase in the number of extreme precipitation days (defined as the top 1% of heaviest precipitation events) has occurred over the Northeast (an increase of around 60%) and Midwest (around 45%), along with increases of more than 10% in their annual and 5-year maximum amount (Figure 2.8). These changes have contributed to increases in river and stream flooding in these regions. The increase in frequency and intensity of precipitation extremes is evident across a broad range of event durations (from 1 to 30 days) and return intervals (1 to 20 years), particularly east of the Rocky Mountains.~~

~~There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the U.S. Paleoclimate records derived from tree-ring growth provide evidence that summer moisture has increased over the past century in parts of New England, the central-eastern U.S. and the northern Mississippi River valley.~~

The following is a more accurate summary of what U.S. data show.

There are regionally-heterogenous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when

beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution to anthropogenic warming difficult.

Along the Pacific coast very few stations (1 or 2 out of 29) exhibit significant trends on any time scale in any metric and the region-wide trends are insignificant. In the Southeast region about 5 out of 24 stations exhibit positive trends in average and extreme precipitation metrics and the regional trends are likewise significant, but only on samples beginning in 1950. When the sample starts in 1873 or 1980 the trends weaken and become mostly insignificant. In the Midwest region nearly half the stations exhibit positive and significant trends in average precipitation since 1893 (23/61) and 1950 (28/61) but the trends weaken after 1980; only 6/61 locations are significant and the region-wide trend is insignificant. These positive trends reflect the dryness of the 1930's Dust Bowl era. Regional trends in max and 99th percentile exceedances are insignificant post-1893 and 1980 but the latter are positive and significant post-1950.

In the Northeast region 12 out of 27 stations exhibit positive and significant increases in average precipitation post-1888, post-1950 and post-1980 (10/27) and the regional trend is positive and significant in all three intervals. The regional number of 99th percentile exceedances has a positive trend post-1950 and post-1980 but not post-1888. The significant positive trends post-1980 are concentrated in NH but are insignificant elsewhere.

Consequently, precipitation in the U.S. exhibits considerable regional and temporal variability. Relatively more places became wetter than drier. In the Midwest and Northeast the general pattern since 1950 favors increased precipitation depending on the location, although trends since 1980 have not tended to be statistically significant.

KEEP IT FOCUSED ON THEIR MISREPRESENTATION OF EXTREME PRECIP

4.2 Heatwaves

- details; NCA4 used entire 20th century while NCA5 looked at post-1960 interval

5 INADEQUATE TRACEABLE ACCOUNTS

Starting with the NCA3, the NCA has included a section on Traceable Accounts at the end of each Chapter. A description from the NCA5:

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"Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team's expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources."

The Traceable Accounts for each Chapter and Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts are in principle an important factor in addressing the NCA's statutory requirement to discuss scientific uncertainties. Further, the Traceable Accounts can help satisfy the Executive Order for Restoring Gold Standard Science with regards to: reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions.

However, the execution of the Traceable Accounts is uneven, often superficial and noninformative in Chapters 2 and 3 (which were the only Chapters investigated here). An example from Chapter 2:

Key Message 2.2: Extreme Events are Becoming More Frequent and Severe.

Description of the Evidence Base consists of two paragraphs, with the first paragraph summarizing the findings and the second paragraph providing a generic description of the types of data that can be used for storms. Major Uncertainties and Research Gaps focuses on the uneven distribution across US populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning, and the lack of homogenized daily and hourly temperature data except from reanalysis products.

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The most astonishing deficiency is in the Description of Confidence and Likelihood. One of the statements in Key Message 2.2 is: "Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence)." The Description of Confidence and Likelihood includes the following statement: "Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher." No reference to journal publications or a specific data set is made in the Chapter regarding hurricane induced precipitation or storm surge to support this high confidence conclusion.

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With regards to Chapter 3, there are some substantial inconsistencies between the Traceable Accounts for the different Key Findings:

Key Message 3-1: Human activities have caused global warming.

Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period." The Uncertainties section only addresses uncertainties in radiative forcing of greenhouse gases.

By contrast, consider Key Message 3-4: Humans are changing Earth System processes.

The Traceability Analysis in this section contains arguably the most scientifically credible text in the entire Chapter. From Description of Evidence Base: "In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals". From Major Uncertainties and Research Gaps: "For example, the true natural variability of the climate system on decadal to

centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.”

As part of the Traceable Account: “Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.” Upon clicking on the eyeball icon above a particular figure, a Contact Us email appears, addressed to the USGCRP. No attempt was made to send a email to elicit the Metadata information, but it is clear that this information is not readily accessible online.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.
—details

~~6 OVERCONFIDENCE WHEN STATING CONCLUSIONS~~

—details

~~7.6 RELIANCE OVEREMPHASIS ON EXTREME SCENARIOS~~

To respond to the GCRA mandate to “project major trends for the subsequent 25 to 100 years,” the NCA relies on projections of future climate change ~~are based on driven by~~ estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.” In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. NCA5 makes the following statements observations about future the scenarios they use:

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“NCA5 authors were advised to assess the full range of scenarios available.” (Front Matter)

“Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency.” (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue The the NCA5 otherwise ignored a the problem large body of literature (summarized in section xxx of the DOE Report) that shows the 8.5 and the 7.0 scenarios to be implausible, and advises against using them for policy making purposes. In 2021, UN Climate

Negotiators (COP) stopped using scenarios above 4.5. The IPCC AR6 published in 2021 stated that "The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments."

Even in the context of NCA5 being advised to assess the full range of scenarios available, a keyword search of the NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, 10 figures only included the 8.5 scenarios: 5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13.

The problem of relying on extreme scenarios is particularly acute for NCA5's sea level rise projections. The sea level rise scenarios used in the NCA5 do not relate directly to the SSP emissions scenarios, but to specified amounts of sea level rise by 2100, whereby Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet). (Table 4 of Guide to Using this Report).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5

Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 3 for regional sea level information. Adapted from Sweet et al. 2022."

Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.23 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

Considering only projections representing processes in whose quantification there is at least medium confidence, the IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m for the (5th–95th percentile range), for all scenarios ranging from RCP2.6 to RCP8.5. The IPCC AR6 cites values as high as 2.4 m at the upper end of the 95th percentile range for RCP8.5, if estimates include the hypothesized Marine Ice Cliff Instability (low confidence). The corresponding

Nevertheless, the range of sea level rise scenarios considered by the NCA5 includes Intermediate-High (from 1.5 m) and High (extends to 2.0 m) values that associated with the implausible extreme emissions scenario RCP8.5 and processes in which there is low confidence in understanding. Further, the NCA5 neglects to include plausible lower scenarios, such as 0.2 m cited by the IPCC, that which also corresponds to the average rate of sea level rise over the past century.

With regards to actual predictions of sea level rise, Chapter 9 of the NCA states: "Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2)." These values of sea level rise encompass the Intermediate scenario to values slightly higher than the High scenario from Table 4. ~~42.~~

Global sea level rise projections to 2050 relative to a 2000 baseline can be evaluated with respect to the observed global sea level rise from 2000-2024, which is approximately 3.39 inches (0.28 feet). [HYPERLINK "https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level"] Hence it is inferred that NCA5 is projecting values of sea level rise between 2025 and 2050 that are 3.5 to 5.8 times the rate observed during 2000-2024.

Chapter 9 further states: "Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches." ~~This analysis accounts for the observed sea level rise between 2000 and 2020. << But they say it's relative to 2020.~~

With regards to confidence levels, NCA5 Chapter 9 Traceable Accounts states: "There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9-13 inches) between 2020 and 2050" ~~Neither the statement nor the context in the paragraph does not distinguish as to whether this refers to global sea level rise, or US average sea level rise, although it is inferred to refer to global sea level rise.~~

In summary, the NCA5 presents future sea level rise scenarios that are not directly relatable either to SSP/RCP emissions scenarios or ~~global~~Global warming Warming levelsLevels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and that include hypothesized ice sheet processes for which there is low confidence. Projections to 2050 require rates of sea level rise ~~during from 2025 through to 2050~~ that are more than three times the rate observed during 2020-2024. Further, the NCA5 ascribes *high confidence* to these sea level rise projections.

~~The~~ In summary, the NCA5 inclusion, and even the focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

87 BIASED SELECTION OF REFERENCES

~~THIS IS WHERE THE RPIR example should go. -details-~~

98 SUMMARY: EVALUATING EVALUATION OF THE NCA5

9.18.1 Pertinent aspects when evaluating in light of statutory requirements

- not our remit to make a ruling but here are aspects to consider in light of statutory requirements

9.28.2 Evaluation from the perspective of expert users of the report

- we have deep knowledge of the topics surveyed by the NCA5 authors
- we do not have confidence that the report was balanced and comprehensive
- we can point to many specific instances in which the report did not exhibit an appropriate level of quality or integrity as a scientific document
- we have reason to believe the whole process, from author selection to handling of expert reviews, was biased towards reinforcing foregone conclusions and alarmist messaging

9.38.3 Evaluation from the perspective of citizens interested in good policymaking

- Public concerns about climate change are valid, as are concerns about cost of living, economic growth, employment, etc.
- We share the general concern that elected officials and those who serve them have the best information available when making important decisions around energy and climate policy
- NCA5 was a missed opportunity: it could have been a valuable input to that process but it did not turn out that way
- consequently its usage is unlikely to lead to better decisions and would more likely increase the error rate in policy formation and we recommend it not be used for policymaking purposes.

APPENDIX 1: Seth's letter on statutory requirements for NCA5

APPENDIX 2: Analysis of 141 U.S. Longterm Daily Precipitation Records.

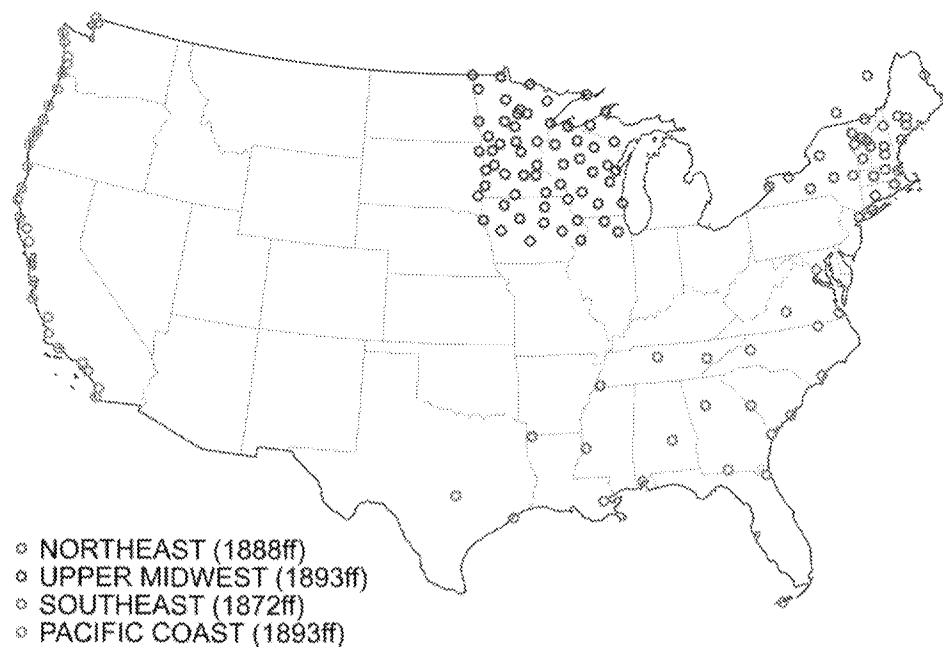


Figure. Stations used in the following analyses.

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure

Column 2: Number of stations in that region

Column 3: Count of stations exhibiting a significant positive trend

Column 3: Count of stations exhibiting a significant negative trend

Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)

Number of 99 th pct exceedances	29	1	0	(-)
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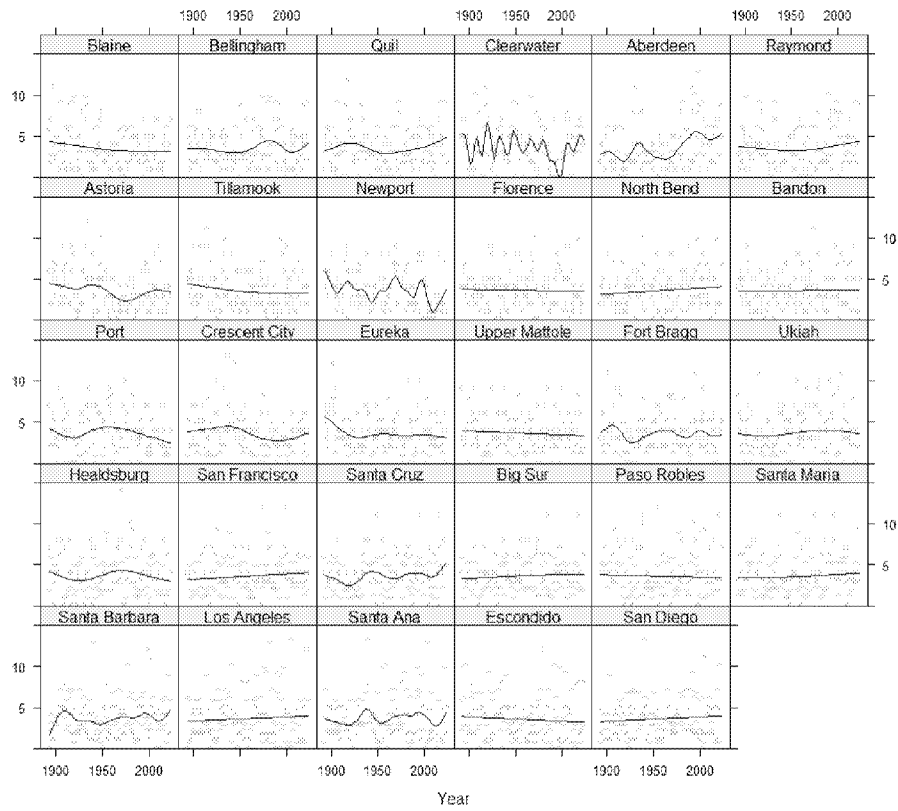
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

Annual No. 99th Percentile Exceedances PC 1893-2024



SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

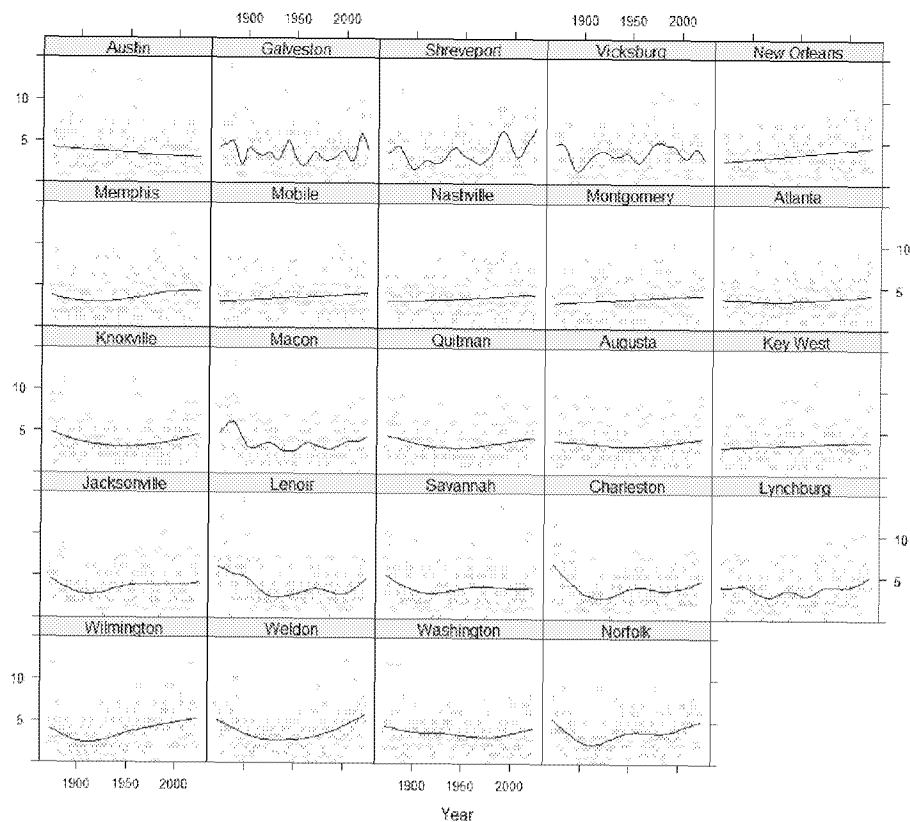
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

Annual No. 99th Percentile Exceedances SE 1873-2024



MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

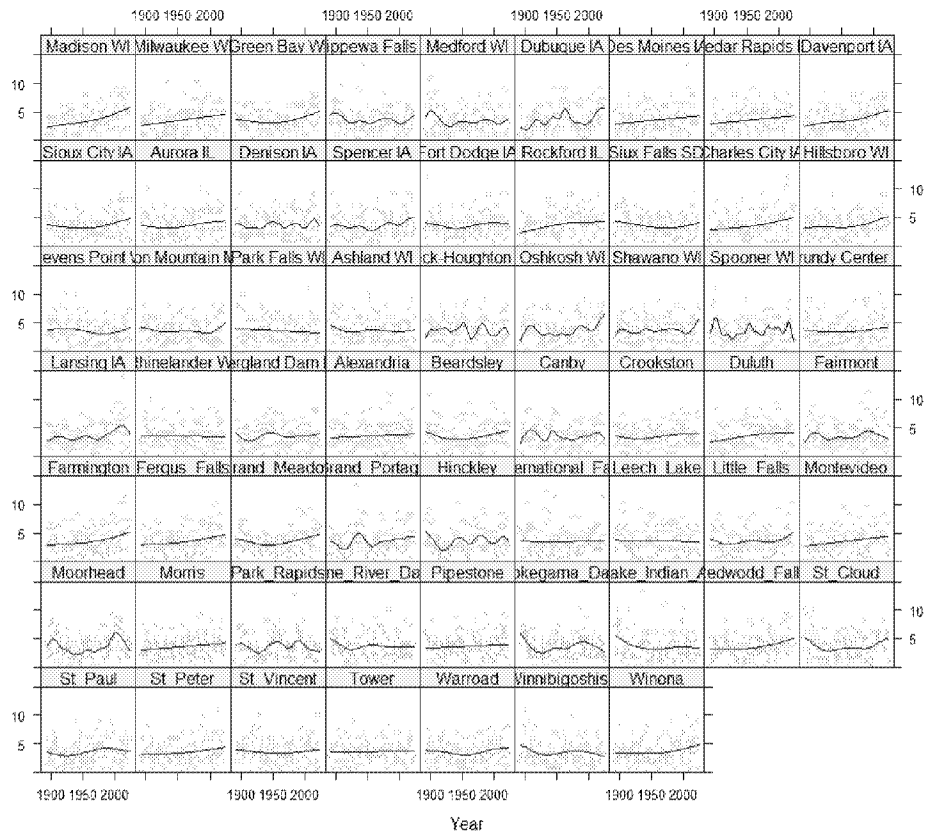
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

Annual No. 99th Percentile Exceedances MW 1893-2024



NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

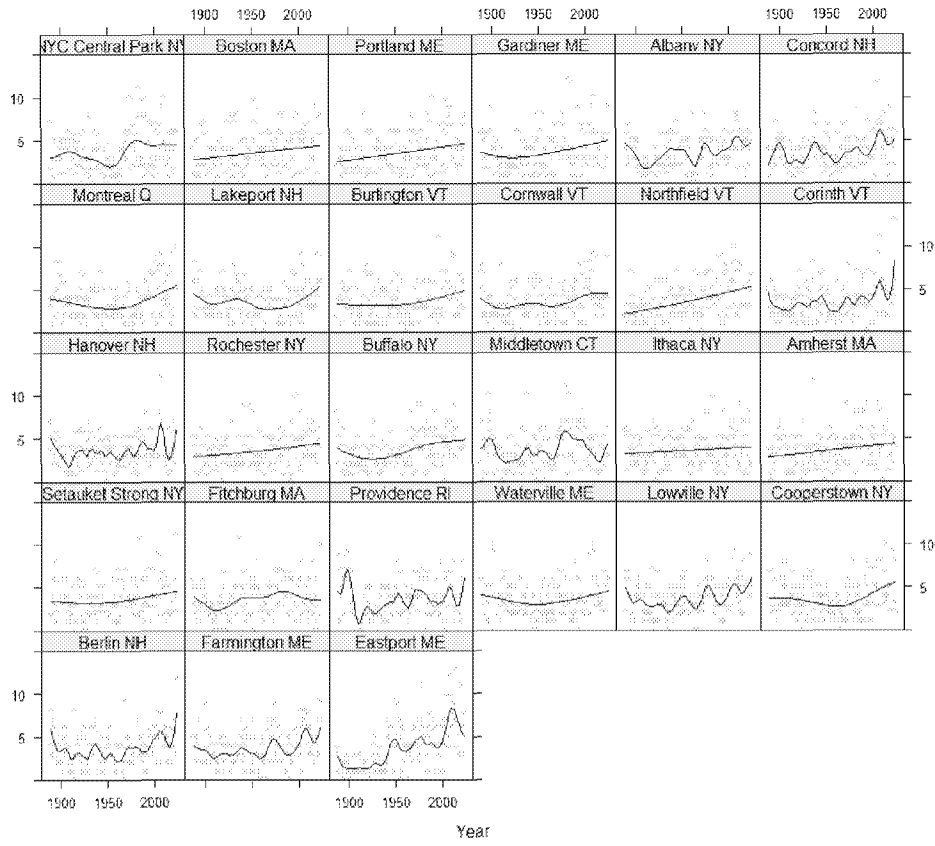
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

Annual No. 99th Percentile Exceedances NE 1888-2024



Section 4.2 Heat Extremes

In contrast to NCA5, NCA4 examined heat extremes across the whole of the 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies:

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[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

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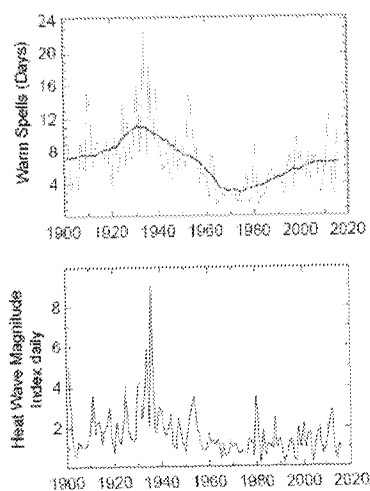
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Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s. (NCA4 pp. 190–191)

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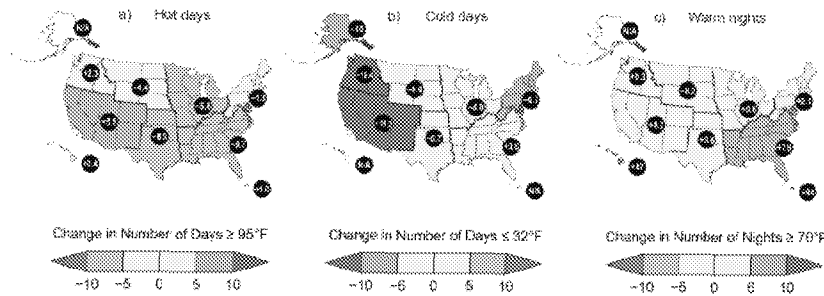
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U.S. Heat waves since 1900. Source: NCA4 Figure 6.4

Contrast this careful and factual language with NCA5 Key Message 2.2: “Extreme Events Are Becoming More frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 reproduced below.

Observed Changes in Hot and Cold Extremes



Hot days have increased in the West, hot nights have increased nearly everywhere, and cold days have decreased.

Figure 2.7. Over much of the country, the risk of warm nights has increased while the risk of cold days has decreased. The risk of hot days has also increased across the western US. This figure shows the observed change in the number of (a) hot days (days at or above 95°F), (b) cold days (days at or below 32°F), and (c) warm nights (nights at or above 70°F) over the period 2002–2021 relative to 1901–1960 (1951–1980 for Alaska and Hawaii and 1956–1980 for Puerto Rico). Data were not available for the US-Affiliated Pacific Islands and the US Virgin Islands. Figure credit: Project Drawdown, Washington State University Vancouver, NOAA NCEI, and CISS NC.

Close inspection shows that this Figure contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of the NCA4. The time scale of analysis for this Figure is stated as the number of hot days, cold days and warm nights (respectively in panels a–c) over the period 2002–2021 compared to 1901–1960. Presumably (though not stated in the caption) the counts are per year. Notwithstanding Key Message 2.2 the leftmost panel shows that over most of CONUS the number of extreme heat days has decreased in recent decades compared to the prior century.

There are mixed (and somewhat convoluted) messages in accompanying discussion in NCA5 regarding the notion that hot extremes are increasing in the CONUS becomes convoluted since it appears to be aimed at supporting the Key Message despite the contrary evidence. From NCA5 chapter 2 these statements relate to extremes in heat elaborates on KM2.2 by saying (p. 16):

[Key Message 2.2] Extreme Events Are Becoming More Frequent and Severe

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Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (high confidence).

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But it does not mention the decline elsewhere. And later in the next page (p. 17) it says:

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The Risk of Temperature Extremes Is Changing

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By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

Reference to a global trend seems to be an attempt to tie heatwaves to climate change, but then the obvious question, unaddressed by NCA5, is why only part of the U.S. follows it while most of the country is trending in the opposite direction. These heat issues were addressed in CWG25 Ch6 of the CWG25, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by the chaotic behavior of natural variability than the small extra forcing from the enhanced concentrations of CO₂. The data shown in CWG25 conclusion shows that in terms of both (a) hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is experiencing no more than was experienced 100 years ago. For example, in the 30-year period 1975-1954, representing only 23% of the 1899-2024 data record, the CONUS experienced 33% of the total heat wave days. The most recent 30-years experienced 24%, almost exactly that expected by chance. Thus, the NCA5 claim that "multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades" is seen to be simply false when expanding the temporal (to 1899) and spatial (entire CONUS) domains to evaluate encompass the all available data that is available (Ch6 Fig. 6.3.6 CWG25).

The NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG Section 8.6.1 discussed this event in detail, reviewing the findings of multiple peer-reviewed studies that explained the unusual meteorological conditions giving rise to it were unrelated to climate change, a point omitted from the NCA5 discussion.

NCA5 finally turns to the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

Several major heatwaves have affected the US since 2018, including a record-shattering event in the Pacific Northwest in 2021. The western US has been particularly affected by extreme heat since the 1980s (Figure 2.7), experiencing a larger increase in days over 95°F , as would be expected given the greater warming in that region relative to the eastern US. By contrast, the [The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator ([HYPERLINK "https://www.globalchange.gov/indicators/heat-waves"](https://www.globalchange.gov/indicators/heat-waves)) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed this issue in CWG25 Section 6.3. The Figure referenced by NCA5 uses an *ad hoc* definition of heat wave, namely two consecutive days with minimum nighttime temperatures above the 85th percentile, and an *ad hoc* time scale which begins in the 1960s, the coldest decade in the last century, thus suppressing any comparison to the 1930s. Nighttime temperatures in urban areas have gone up faster than daytime temperatures (which the NCA5 acknowledges), but this is a signature of urban heat island effects and is not a good metric of climate change. CWG25 noted as well that the occurrence of hot days ($\geq 95^{\circ}\text{F}$) has recently increased in the West, but declined in the remainder of the country and in the nationwide average, since 1899.

Nighttime temperatures are rising faster than daytime temperatures, and the number of nights where the temperature never falls below 70°F is increasing everywhere in the US except the

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~~Northern Great Plains (Figure 2.7). The extent of CONUS experiencing hot summer nights is growing at a faster rate than the extent experiencing hot summer days.~~

~~While the statements above may be factually correct, they are misleading because they are factually incomplete. The NCA5 focused much of the heat discussion on what was experienced in the West since the 1980's, as well as rising nighttime temperatures since the 1960's. It only briefly mentions the long-term decline in heat extremes in most of the CONUS. We also note the convoluted reasoning in the quote above that hot extremes are apparently due to "greater warming" in the western region than experienced elsewhere and that declining hot extremes elsewhere are "due to summer cooling trends". Since "trends" do not cause changes, one might ask, "What caused the warming and cooling trends?"~~

~~The NASEM Review failed to raise any of these issues, provided few comments on the explicit issues of assessing the changes in extreme temperatures. Much of its review it focused on social and policy issues (e.g., Comments on Equity and Justice), rather than on the confidence we have in the scientific assumptions that elicited the social and policy discussion underlying science. In our assessment, the NASEM review lacked the normal rigor in which questionable claims and analysis are challenged. NASEM failed to apply the serious rigor one would expect. A few extracted comments from the NASEM review with our remarks are below will illustrate. Note that NASEM review comments are included here in blue font for reference. NASEM praised the section as a whole by saying:~~

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~~The chapter [2] meets the requirements of Section 106 of the GCRA.~~

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~~This NASEM statement is of some concern as the chapter yet contrary to the requirements of Section 106 the NCA5 did not thoroughly address discuss natural variability nor did it let alone assess the full climate record available for analysis that would aid in for quantifying natural variability. Chapter 2 actually minimizes natural variability by claiming (unsubstantiated) skill in attributing recent extremes to human causes. For example NCA5's Chapter 2 Introduction states,~~

~~"...recent advances in attribution science (KM [HYPERLINK "https://nca2023.globalchange.gov/chapter/3"/\ "key-message-3"\t "_blank"]) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."~~

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~~-CWG25 reviews the expert literature demonstrates demonstrating that this particular event would have happened in any case with or without climate change and that for the CONUS, hot extremes are no more frequent now than they were in the past. NASEM did not challenge the unsubstantiated attribution claims in the NCA5.~~

~~Notwithstanding NASEM's claim that the section complies with Section 106 of the GCRA it then acknowledged the absence of discussion of natural variability:~~

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~~...the discussion and references regarding the role of natural climate variability and its regional differences are missing.~~

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~~This comment is correct, but difficult to find explicit comments on in the NCA5 given that NCA5 neglected to examine over half of the available CONUS climate record which begins in the late 19th century—a period obviously dominated by natural variability. While a nod to natural variability is~~

occasionally found in NCA5, it is usually followed by a “however” to emphasize human influence. One example is the statement just before the claim mentioned above, NCA5 pertaining to extreme event attribution: “There has always been extreme weather, which occurs even in an unchanged climate due to the natural variability of the Earth system. However, recent advances in attribution science (KM [HYPERLINK “https://nca2023.globalchange.gov/chapter/3”\l “key-message-3”\t “_blank”]) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017”

We pointed out that the evidence regarding heatwaves directly contradicts Key Message 2.2. NASEM did not mention this, instead it focused on a somewhat esoteric issue of terminology:

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“Extreme Events Are Becoming More Frequent and Severe.”

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Key Message 2.2 is another generally well written key message. However, while the title of this key message includes the word “risk,” the key message is exclusively about hazard. The Committee suggests rewriting the key message title to more accurately reflect the discussion on hazards.

The NASEM review appears to accept the NCA5’s use of short data records going back only to the 1960’s and 1980’s because it makes no critical remarks about the NCA5’s neglect of the available evidence to failure to assess longer time scales and the broader geographic area (CONUS) long time series, except for its observation that the use of short records makes the omission of natural variability that much more of a problem. Rather, the NASEM review of Key Message 2.2 is only concerned about the title rather than its misleading content.

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It is also important to point out that the influence of natural climate variability becomes particularly strong when the climate trend is computed based on short periods of time or small geographic areas.

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This comment was largely ignored in the NCA5 final text.

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~~These heat issues were addressed in Ch6 of the CWG25, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by the chaotic behavior of natural variability than the small extra forcing from the enhanced concentrations of CO₂. The CWG25 conclusion is that in terms of both (a) hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is experiencing no more than was experienced 100 years ago. For example, in the 30 year period 1925-1954, representing only 23% of the 1899-2024 data record, the CONUS experienced 32% of the total heat wave days. The most recent 30 years experienced 24%, almost exactly that expected by chance. Thus, the claim “multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades” is simply false when expanding the temporal (to 1899) and spatial (entire CONUS) domains to evaluate the data that is available (Ch6 Fig. 6.3.6 CWG25).~~

Regarding hot days, Fig. X below displays the occurrence of days $\geq 95^{\circ}\text{F}$, showing the increase in the three western regions and declines elsewhere. The trends in both heatwave days and hot days are (insignificantly) negative for the CONUS as a whole.

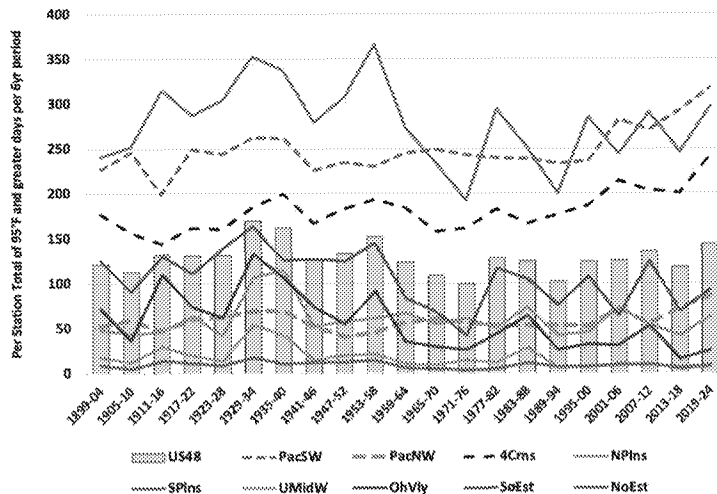


Figure. Number of days $\geq 95^{\circ}\text{F}$ in 6-year periods (1899-2024) for nine CONUS regions (lines, dashed positive trends, solid negative trends) and full CONUS (bars).

The fact (and we agree it is a fact) that summer nighttime temperatures have risen rapidly since 1960 nearly everywhere, and especially in the largest cities, is clear. However, and not explicitly pointed out in NCA5, this observation is more a consequence of the urban heat island effect (which has greatest impact on nighttime temperatures and on stations changing from rural to semi-rural, Ch6 CWG25) and the choice of starting in the 1960's, the coolest decade since the 1910's.

In attributing claims of rising heat extremes to GHG concentrations, the NCA5 concentrated on the West but is silent on the attribution of declining heat extremes in the eastern 2/3 of the CONUS (the statement "due to summer cooling trends" does not suffice) or the major role that the increasing growth of infrastructure around the stations exerts on nighttime temperatures. The scientific method requires one to demonstrate that a claim must represent all of the evidence, not simply a small portion that agrees with the claim. In this instance the NCA5 falls short of rigorously demonstrating that rising GHG concentrations are responsible for the observed changes (or lack thereof) in hot extremes in the CONUS which are more fully explainable by natural variability (1930's Dust Bowl, cool 1960's) and urbanization (nighttime warming).

Review of the Fifth National Climate Assessment

[TOC \O "1-3" \H \Z \U]

1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix XX) that we assess the suitability of the Fifth National Climate Assessment for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, NASEM review of the Third Order Draft and the USGCRP responses to the review. We have drawn upon our long experience working on advisory reports, including for the NASEM, IPCC and other organizations, as writers, reviewers and project leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of the science as of its publication date in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted "CWG25"). The overall effect of ~~its~~ ~~the~~ biases and omissions of NCA5 is an excessively dire picture of climate risk.

Our report begins with background on the National Climate Assessments. We then discuss the standards by which we have assessed NCA5, followed by specific deficiencies that we have ~~identified~~ identified.

1.2 About the National Climate Assessments

The U.S. Global Change Research Program (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change, but also sought to identify potential adaptation measures and identify the highest priorities for future research.

- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences.
- NCA4 (2017/2018) was an expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science. NCA4 introduced a traceability analysis for each key finding, including a cursory description of uncertainties.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on "Climate Action" and policy recommendations with a social justice emphasis. NCA5's self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA's statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (see the Box nearby for an example). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

Good climate and energy policies will balance the risks and benefits of a changing climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics—the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects are the only people who can bring the facts to the discussion and so have a unique responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.

Because climate is at the core of human existence, it can engender passion and emotion. Indeed, some younger climate scientists have gone into the field to "save the planet." So it isn't surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. When that happens, it This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.

Philip Handler, President of the National Academy of Sciences, identified the problem in a 1990 [HYPERLINK "https://science.sciencemag.org/content/208/4448/1093"] that resonates eerily four decades later:

~~Difficulty arises in the scientific community from confusion of the role of scientist and scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.~~

In Appendix XX we include a letter of guidance from the Office of General Counsel, U.S. Department of Energy, summarizing the extent of statutory requirements governing USGCRP work products in general and NCA products in particular.

We can summarize the standards applicable to the NCA as follows:
- details.

Beyond the statutory requirements we draw attention to two other pertinent standards. President Trump's executive order of May 23, 2025, "[[HYPERLINK "https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/"](https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/)]" enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some have found them [[HYPERLINK "https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science"](https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science)].

~~Finally, we~~ We consider that when scientific reports are being assembled that will be highly influential on climate policymaking there are other desiderata, including statements about the strength of climate knowledge. The IPCC's approach is based on judgment of the available evidence and agreement among experts. ~~More sophisticated knowledge characterizations for risk management~~ include: [REFERENCE AVEN](#)

- The degree to which the assumptions made are reasonable/realistic based on background knowledge—concern about the focus on implausible emissions scenarios RCP8.5/SSP5-8.5
- The degree to which data/information exists and are reliable and relevant—the historical and paleo database is inadequate for a complete characterization of natural climate variability on multi-decadal to millennial time scales
- The degree to which there is disagreement among experts (including those from different environments or academic fields)—attempts to suppress disagreement and alternative perspectives among experts

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- The degree to which the phenomena involved are understood and accurate models exist—concerns about the fidelity and utility of climate models
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns and—neglect of the unknown knowns associated with natural climate variability

Good climate and energy policies will balance the risks and benefits of a changing climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a unique responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

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Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

1.4 When Peer-Review Fails: An Example from NCA4

Peer-review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, NCA reviewers self-select on a volunteer basis whether to provide comments and what parts of the report to read, whereas in academic journals Editors recruit reviewers and assign them to specific papers. There is no guarantee that any particular section of an NCA report was reviewed by anyone, let alone by someone with a different perspective than the authors. This is a problem with NCA and IPCC reports since over the years many potential reviewers have given up making the effort, because their input has systematically been ignored. Second, and related, NCA authors have near complete authority whether to accept or reject review comments. Here, for example, is how a review comment critical of a section of the NCA5 draft was handled by the authors:

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REVIEWER COMMENT

Tropical Cyclones/hurricanes have not increased (Klotzbach, P.J., Bowen, S.G., Pielke, R. and Bell, M., 2018. Continental US hurricane landfall frequency and associated damage: Observations and future risks. Bulletin of the American Meteorological Society, 99(7), pp.1359-1376., Pielke, R., 2021. Economic Normalisation, And disaster losses 1998, A 2020: A literature review and assessment. Environmental Hazards, 20(2), pp.93-111.)

US NCA RESPONSE

Thank you for your comment.

This comment is inconsistent with the author team's thorough assessment of the science.

By contrast in academic journals the Editor mandates the authors' response and the reviewer gets to assess its adequacy. Third, once an NCA chapter author team has been selected publication of their work is guaranteed, whereas academic journals routinely reject papers if they do not pass review.

These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were "peer reviewed". But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a Figure that completely misrepresented the underlying data and which evaded peer review to do so. Further

START BOX

NCA4's Figure IX.5: A Tale of Deception and Review Failure

A disappointing example of NCA4's misrepresentation of climate science involves U.S. temperature extremes. Here is a summary of the issue; details can be found in Koonin (2024).

As we pointed out in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Taking cold and hot extremes together the U.S. climate has become more moderate over time. NCA4's Part I (Climate Science Special Report, CCSR) says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

and offers this figure in support:

Record Warm Daily Temperatures Are Occurring More Often

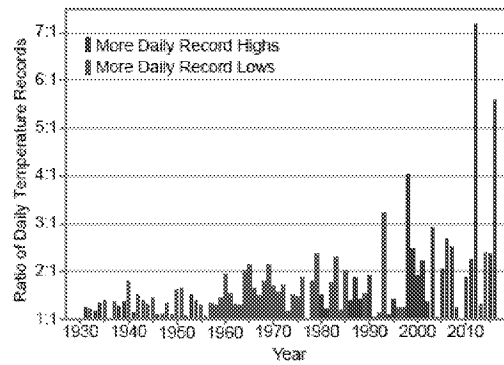
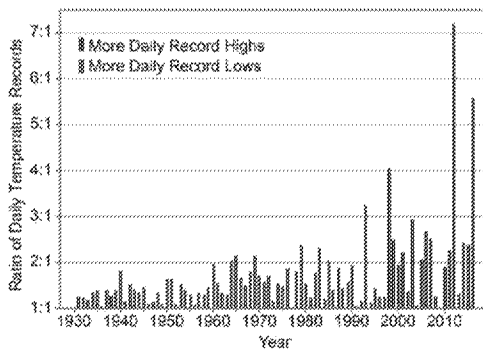


Figure ES.5: Observed changes in the occurrence of record-setting daily temperatures in the contiguous United States. Red bars indicate a year with more daily record highs than daily record lows, while blue bars indicate a year with more record lows than highs. The height of the bar indicates the ratio of record highs to lows (red) or of record lows to highs (blue). For example, a ratio of 2:1 for a blue bar means that there were twice as many record daily lows as daily record highs that year. (Figure source: NOAA/NCEI). From Figure 6.5 in Chapter 6.

Record Warm Daily Temperatures Are Occurring More Often



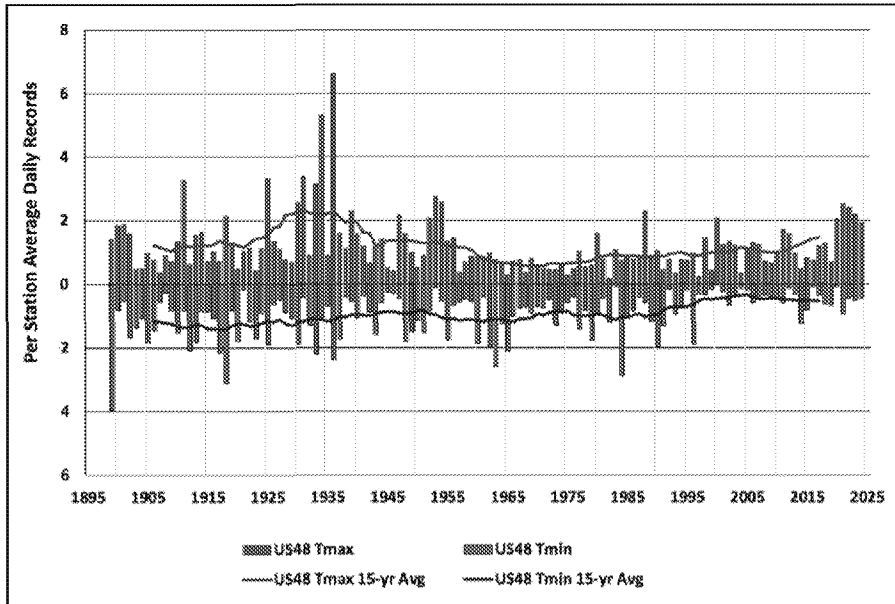
The Figure appears to validate the claim that, as the title says, record warm daily temperatures are occurring more often. But the underlying data do not: they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as NCA4 Figure 6.4 later shows. Figure ES.5 does not show what its title implies: these are not simple counts of cold and warm extreme events, instead they are ratios of the two. In fact both types of extremes declined over the sample interval but cold events declined more than warm events, so the ratio of warm extremes to cold extremes went up. By graphing the ratio in this way the NCA4 created a visual impression opposite to what is in the data. **655R-Figure ES.5** The ratio of the number of daily-record high temperatures to daily-record-low temperatures for many stations across the 48 contiguous states is shown for each year from 1930 to

2017. The lighter bars show a year in which there were more record highs than lows, while the darker bars show years in which there were more record lows than highs. The height of the bar indicates the ratio of record highs to record lows for each year. For example, a ratio of 2:1 for a dark bar means that the stations had twice as many record daily lows as record daily highs for that year. [CSSR, 2017]

Commented [A2]: Cite CSSR

Three idiosyncratic choices combine to generate the figure's seemingly alarming rise in recent decades. First, because the record extremes tallied are defined conventionally (i.e., each more extreme than any preceding value in the history), the numbers of record highs and record lows are both expected to decline through the years (it becomes increasingly unlikely that a record will be exceeded). Second, the graph displays not the numbers of record highs and lows, but rather their ratio. And finally, the history begins only in 1930, when, in fact, data exist beginning in the late 19th Century. The upshot of these choices is that the resultant figure is guaranteed to show a long period of quiescence around followed by dramatic variations, creating the impression of large changes in recent decades, even if they aren't present.

Figure 6.3.3 of our report [CWG25](#) (reproduced below) shows the results of a proper analysis – defining each record as the singular extreme in the history, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. On the cold side, the Valentine's Day Arctic outbreak in Feb 1899 stands as the most extensive cold extreme experienced by CONUS, with 1917 in 2nd place. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the extreme Tmax records were achieved in the last quarter, in accordance which is consistent with statistical expectations. As a result, the ratio shown in the CSSR explodes in recent decades. And – The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate less prone to extremes, in sharp contrast to the title of the CSSR figure, "Record Warm Daily Temperatures Are Occurring More Often" the message of the NCA4 Figure.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3.

The National Academies' expert review panel [[HYPERLINK "https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report"](https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report)] the discussion of temperature extremes in a [[HYPERLINK "https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf"](https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf)] of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) [[HYPERLINK "https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf"](https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf)] to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The "new figure" referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies' panel. It seems unlikely that the Academies panel ever saw that figure because they

surely would have commented if they had and it wouldn't have survived to publication. And the figure's problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

While the following statement has far less headline potential than that from the CSSR's page 19 quoted at the beginning of this box, it has advantage of being correct:

There have been some changes in temperature extremes across the contiguous United States. The annual number of high temperature records set shows no significant trend over the past century (nor over the past 40 years) but the annual number of record cold nights has declined by a factor of 4 since 1895, somewhat more rapidly in the past 30 years.

Commented [A3]: Check this statement

Commented [A4R3]: R^2 is 0.02, so not significant for 1978-2017.

END BOX

With this background we now present our critique of NCA5.

2 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND NON-SCIENTIFIC TONE

The opening Chapter 1 "Overview" holds a prominent place since it serves as a summary of summarizes the whole report and is all the only section that many will read. While Although the later Chapters of NCA5 contain there is much sound scholarly content, in the later sections of NCA5, Chapter 1 is marred by a pervasive tone and language aggressively use of advocacy language and a tone overly focused on promoting aggressive emission reduction policies. The authors must have known this chapter would be mined for quotes by the media and activists looking to add an imprimatur of scientific authority to oversimplified declarations of opinion. Many examples can be cited; here we provide note a few that are particularly egregious ones.

The chapter Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes all warming is anthropogenic in origin, all warming is bad and causes economic damage, warming causes extreme weather to intensify. Such sweeping generalizations go well beyond what science has or can establish. A scientifically-sound version of this paragraph would instead say something like the following:

Commented [SK5]: There's also no quantification. Perhaps risks increase, but how big were they to begin with?

The Earth is undergoing a warming trend caused because of by a combination of natural and anthropogenic influences. This warming can be expected to will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. There is evidence that Some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases can might slow the warming process although such policies have proven to be very expensive costly and disruptive, so the costs need any climate actions to be weighed against the potential benefits.

On the next page the Overview goes on to say:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits..."

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms, indeed (as is acknowledged in Chapter 19 on Economics) in some cases it is

~~expected to yield benefits there will be benefits. Nor is climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is~~ It is a disservice to policymakers ~~not to be honest about this.~~

Page 9 promotes renewable energy options by ~~arguing~~ noting, correctly, that the “levelized” costs of wind/ and solar power generation have fallen sharply since 2010. But “levelized” refers to the lifetime project cost averaged over all power production and ignores the intermittency problem: namely solar and wind are not always available. It results in an invalid comparison since even if, for instance, the levelized cost of solar energy per megawatt-hour falls below that of coal, coal power is available continuously and on demand whereas solar is not. The proper comparison would adjust for the difference in availability by considering the cost of supplementing solar and wind with backup natural gas-fired systems or battery storage, and on that basis renewable energy remains prohibitively expensive. Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through gas, fission, or storage) more than doubles the cost of electricity. Further, there are yet unmet synchronization challenges in wind/solar-heavy grids. Here again it is a disservice to readers ~~advisory malpractice not to acknowledge these facts.~~

Page 14 presents future emission scenarios with the following description: “Climate modeling experts develop global climate projections for a range of plausible futures.” The word “plausible” is applied to all the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The figure does not contrast observed emissions against ~~model~~ previous projections nor does it caution readers that §§SP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as “plausible” the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline “business-as-usual” future.

Commented [SK6]: Perhaps we should cite the relevant text from NCA5 Box 1.1 (pg 1-8): Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources (Figures 1.2, 1.3). (5.3, 12.3, 32.1, 32.2; Figure A4.17)

Commented [SK7]: Didn't AR6 WG1 deem 7.0 and 8.5 scenarios “low likelihood”?

~~[We could criticize Figure 1.6, which uses an anecdote to support its 1200 claim.]~~

Page 17 (and elsewhere) invokes the NOAA Billion Dollar Dataset as an indicator of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) §since it measures the growth of the economy not the frequency of extreme weather and indeed NOAA has withdrawn the data product. Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends.

Commented [SK8]: They actually say this, sort of, on pg 1-17, but don't make the effort to untangle hazard vs risk, and go on to blame it all on climate change

Page 23 states, in large font:

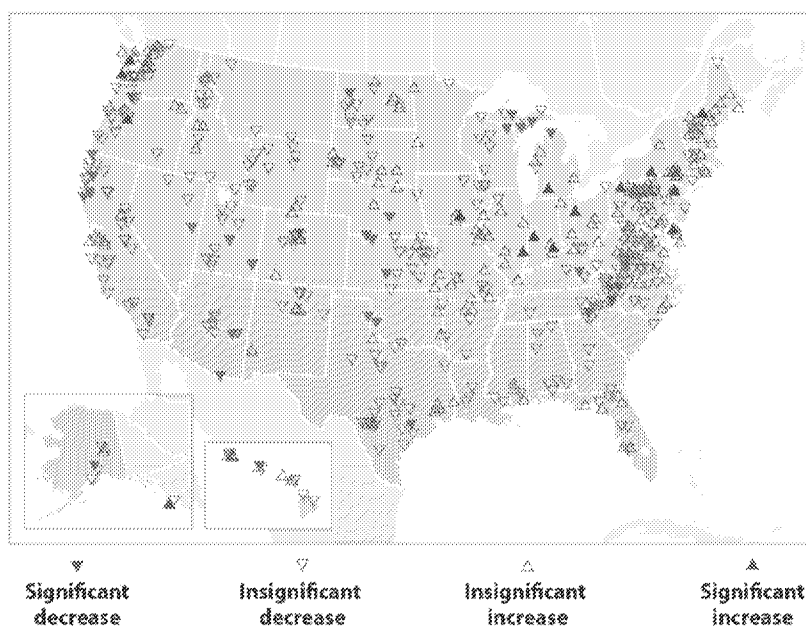
Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

Commented [SK9]: Some climate changes are benign or even beneficial.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote hysteria, but also the ineffectiveness of the review process at not ensuring such statements are removed.

We won't try to cite all the remaining examples of advocacy and hyperbole in the Overview chapter; one more example will suffice. Page 26 states “Increasing flooding puts more people and assets at

risk.” The accompanying figure contrasts model-projected flood losses by county in 2050 to that observed in 2020 as estimated in Wing *et al.* (2022)¹. Hence the evidence for the claim is not currently-observed trends, it is a model-generated projection of changes. But current trends in U.S.-based flooding reveal a more complex picture with a general overall trend towards less flooding. The Environmental Protection Agency’s “Climate Change Indicators: River Flooding” webpage² shows maps both of flood magnitude and frequency. Both show more regions experiencing declines over 1965-2015 than increases. Hence current trends indicate generally declining U.S. flood risks, but the NCA5 Overview not only fails to mention this but declares the opposite based on a single study presenting model-generated forecasts of flood activity decades in the future.



U.S. Flood magnitude trends 1965-2015.

Source: [HYPERLINK "<https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding>"]

¹ Wing, Oliver, William Lehman, Paul Bates *et al.* (2022) Inequitable patterns of US flood risk in the Anthropocene. *Nature Climate Change* 12 156—162 [HYPERLINK "<https://www.nature.com/articles/s41558-021-01265-6>"]

² [HYPERLINK "<https://www.epa.gov/climate-indicators/climate-change-indicators-river-flooding>"]

3 ONE-SIDED OVERSIMPLIFICATIONS IN SCIENCE SUMMARY CHAPTERS OVERCONFIDENCE WHEN STATING CONCLUSIONS

Chapters 2 (Climate Trends) and 3 (Earth Systems Processes) form the scientific core of NCA5. As we will show in the following examples, they fail to meet statutory requirements to discuss scientific uncertainties and the role of natural variability, and they fail to meet the more stringent implicit standards expected of a policymaking policy-informing report.

3.1 Inappropriate Certainty Grading Inflated Certainty Levels

A general pattern in the NCA5 is overconfidence in stating conclusions. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated certainty levels.

The NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of the NCA5 states that “confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.”

Table 1 provides calibrated language for confidence assessment:

Very high:-	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:-	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:-	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought
Low:-	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggested/suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in the conclusions.

Even within the context of this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. Several illustrative examples are provided.

Key Message 3.1 Traceable Account states: “There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.” Compare the NCA5 ~~this~~ statement with statements from the IPCC AR5 and AR6:

AR5: "It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together." (IPCC, 2013)

AR6: "The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warmings since 1979." (IPCC, 2021)

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While the NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, the AR5 refers to "*more than half* of the observed warming" and the AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

NCA5 Key message 2.2:– "Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*)."

No justification is provided in Chapter 2 for the *high confidence* conclusion on higher storm surges or hurricanes causing heavier precipitation. The Traceable Accounts section, Description of Confidence and Likelihood states:– "Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have *high confidence* that storms are delivering more rainfall and high confidence that storm surges are becoming higher." In short, the NCA5 provides no observational basis or published research for their *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges; and does not meet its own standards for a *high confidence level*.

3.2 Range of Increased Lower Bound of Climate Sensitivity

The promotional tone of Chapter 1 is carried forward into Chapter 3 (Earth System Processes) where states, on page 3-10, Key Message 3.2:– states "The Estimated Range of Climate Sensitivity Has Narrowed by 50%". Referring to Equilibrium Climate Sensitivity (ECS) the section elaborates:

Recent improvements in the understanding of how climate feedbacks vary across timescales have narrowed the estimated *likely* range of warming expected from a doubling of atmospheric carbon dioxide by 50% to between 4.5°F and 7.2°F (*high confidence*).... This uncertainty reduction results from advances in combining observations and targeted modeling results from nearly independent lines of evidence, each of which generally agrees on the values of ECS. The lines of evidence include 1) observed present-day variations on monthly to interannual timescales from which cloud and other climate feedbacks are inferred; 2) observed temperature changes between the preindustrial period and present and associated relationships to ERF; and 3) estimated temperature and radiative forcing changes for multiple warm and cold periods in paleoclimate records.

The graphic summary on page 3-11 states

The reduced uncertainty in climate sensitivity and climate feedback has been achieved through unprecedented quantitative synthesis of evidence from observed changes over recent decades, the industrial era, and paleoclimate.

This is a ~~very grossly~~ inadequate description of the situation. The key development in AR6 was a *reduction* of confidence in the ability of climate models to identify ECS and the shift away from the model-based method the IPCC had relied on since AR1 in 1990. The IPCC instead turned to data-driven ECS estimation and specifically chose a single paper from the scientific literature, Sherwood *et al.* (2020³) for the purpose. It combined paleoclimate data, modern instrumental data and modern observations of climate processes, mainly cloud-related, that govern key feedbacks. Sherwood *et al.* used a subjective Bayesian method to determine the likely range of ECS values. The Bayesian approach begins with the researcher specifying a “prior”, namely an expectation of ~~the likely distribution of what the answers will be~~ before seeing the data. In this case the prior consists of an expected ECS range based on the researchers’ subjective beliefs. Then the data are allowed to influence the ECS distribution and the final result is a weighted average of the assumed prior and the data-driven result. Sherwood *et al.* found a best (or median) ECS estimate of 5.4°F (3°C), which was close to previous model-based estimates but raised the likely lower bound by 1.7°F from 2.5°F to 4.2°F. The IPCC accepted this result and increased the best estimate to 3.1°C.

The NCA5 was published in November 2023. Well before that, in September 2022, Lewis (2023) had been published online at *Climate Dynamics* presenting a forceful critique of Sherwood *et al.*⁴ One of Lewis’ points was that Sherwood *et al.*’s result was dependent on their chosen subjective prior. Lewis recommended using an objective Bayesian method, which places primary weight on the data rather than the researcher’s expectation. Using that and updated forcing data from AR6, Lewis estimated an ECS best estimate of ~~3.74.0°F~~ (2.2°C) with a likely lower bound of ~~2.9°F~~ (1.6°C).

Hence, in contrast to the promotional language of Chapter 3 a more valid summary of the ECS literature as it stood at the time of writing the NCA5 would be what we wrote in CWG25 (emphasis added):

For the AR6, the IPCC placed primary weight on the results of Sherwood *et al.* (2020) that combined historical and paleoclimate proxies with the process-based approach and yielded a best estimate of 3.1°C with a *likely* range of 2.6-3.9°C. Lewis (2022) raised a number of concerns about this result, including methodological errors, outdated input values, and use of subjective versus objective Bayesian priors in the analysis. Lewis’ analysis found that climate sensitivity is estimated to be much lower and better constrained than in the Sherwood *et al.* analysis – median 2.2°C (1.8–2.7°C in the 17–83 percent *likely* range, and 1.6–3.2°C in the 5–95 percent *very likely* range). **The IPCC AR6 estimated only a 5 percent probability that ECS was below 2.3°C, whereas Lewis estimated it to be over 50 percent.** The most recent publications on the debate between Sherwood *et al.* and Lewis further defend their respective positions: Sherwood and Foster (2024) and Lewis (2025).

~~3.3 Presenting New Emission-emission Scenarios-scenarios as as a Scientific scientific “Advanceadvance”~~

³ Sherwood, S. C., Bony, S., Boucher, O., Bretherton, C. S., Forster, P. M., Gregory, J. M., & Stevens, B. (2020). An assessment of Earth’s climate sensitivity using multiple lines of evidence. *Reviews of Geophysics*, 58(4). [HYPERLINK “https://doi.org/10.1029/2019rg000678”]

⁴ Lewis, N. (2023). Objectively combining climate sensitivity evidence. *Climate Dynamics*, 61(9–10), 3155–3163. [HYPERLINK “https://doi.org/10.1007/s00382-022-06398-8”]. The final citation for this paper is Lewis (2023) because the print edition did not appear until 2023, but the article was accepted in August 2022 and the online edition appeared and was in circulation in September 2022.

Chapter 3 pp. 13-14 treats the release of new emission scenarios as a scientific “advance” without addressing the failure of many previous scenarios to match reality or providing an honest assessment of the likelihood that the new ones ~~are~~ remain biased in the same way.

Key Message 3.3 states “New Data and Analysis Methods Have Advanced Climate Science” and includes the following:

New scenarios of socioeconomic development, and their associated emissions and land-use changes, drive updated climate projections from Earth system models. The Scenario Model Intercomparison Project (ScenarioMIP) organized the main set of 21st-century projection experiments under the latest phase of the Coupled Model Intercomparison Project, CMIP6. These CMIP6 projections used newly developed scenarios based on Shared Socioeconomic Pathways (SSPs; Figure 3.4). Five SSPs represent alternative plausible trajectories of 21st-century GDP and population growth and the pace and pervasiveness of socioeconomic and technological progress within individual nations and across the world (see Table 3 in the Guide to the Report). SSP-specific drivers are used in integrated assessment models (IAMs) to simulate the corresponding evolution of the energy system and the resulting greenhouse gas trajectories. These are in turn used by ESMS to drive their 21st-century projections.

There is nothing wrong with NCA5 discussing the development of new emission scenarios which serve as inputs to climate change projections and impact studies. But it is a serious omission not to inform the reader of the failure of many previous IPCC scenarios to match reality and the tendency of the scenario groups to exaggerate near-term and long-term CO₂ concentration growth (CWG25 3.2.1). It is also a serious omission not to caution readers that many climate impact studies use RCP8.5 which by the time of NCA5 had already been heavily criticized in the literature.

The same section also reports the availability of new and larger model ensembles as a scientific advance, without addressing ways in which models are getting worse in some key respects (CWG Ch 5).

~~3.4 Uncritical Promotion of “Emergent Constraints” and uncertainty in climate projections~~

Chapter 3 page 17 presents the topic of “emergent constraints” in uncritical terms:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as “emergent constraints.” The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as a way to tie GCM behavior to climate observations in hopes of generating insight into real-world ECS. Climate models exhibit a wide range of sensitivities. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could check if the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a large proliferation of proposed correlations with little physical motivation. Many emergent constraints patterned on CMIP5 models failed to work on CMIP6 models (Schlund *et al.* 2020)⁵. In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the Earth climate system. The result was that emergent constraints estimated on CMIP5 models widened the range of estimated ECS values when applied to CMIP6 models.

Schlund *et al.* summarized the problem as follows:

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great “advance” that reduced uncertainty.

2.2 Increasing hurricane intensity

NCA5 Key message 2.2 states

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“Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*).”

No justification is provided in Chapter 2 for the *high confidence* conclusion on higher storm surges or hurricanes causing heavier precipitation. The Traceable Accounts section, Description of Confidence and Likelihood states:

“Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have *high confidence* that storms are delivering more rainfall and high confidence that storm surges are becoming higher.”

In short, the NCA5 provides no observational basis or published research for their *high confidence* assertions that hurricanes are causing heavier rainfall and higher storm surges; and does not meet its own standards for a *high confidence level*.

⁵ Schlund, Manuel, Axel Lauer, Pierre Gentile, Steven C. Sherwood, and Veronika Eyring (2020) Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6? *Earth System Dynamics* 11 1233-1258 [HYPERLINK“https://doi.org/10.5194/esd-11-1233-2020”]

3.53.6 Overstating Findings-findings in Underlying-underlying Sourcesources

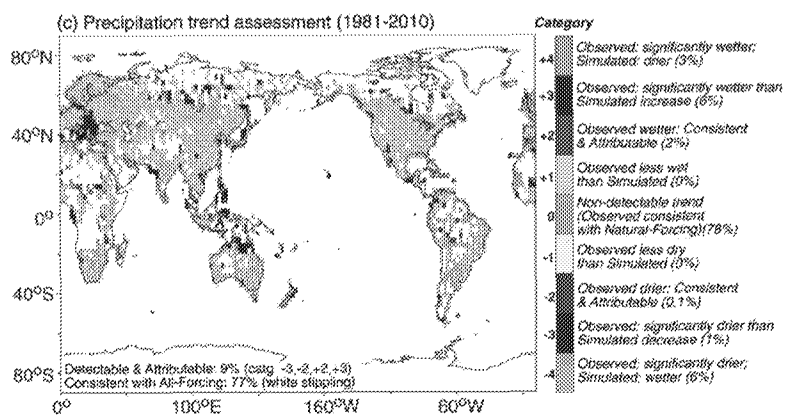
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Although we did not do a detailed audit of the NCA5's use of source material, a few spot checks turned up evidence of a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in central and eastern US based on a comparison of 2002-2021 average rainfall to the average over 1901-1960. Note that this a non-standard metric; we will discuss NCA5's inconsistent choices of time scales of analysis below. The change in this case is called a "trend" even though this is not how a trend is measured, and says that it is "attributable to climate change". The claims were attributed to the following paper:

- Knutson, Thomas and Fanrong Zeng (2018) "Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends" *Journal of Climate* 31(12)
-[HYPERLINK "<https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml>"]

But Knutson and Zeng did not say these things. It examined linear trends over 1901 – 2010, 1951 – 2010 and 1981 – 2010. It did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 – 1960, indeed it was published in 2018 so it could not have. With regard to 1981-2010 trends its results were summarized in the following figure:



Gray indicates no trends detected. Stippling means that there were no trends in the models either so the models and observations agreed in that respect. Detectable and attributable trends were found over only 9% of the land surface of the Earth. Over the US there are detectable trends over only a few regions in the Southwest.

Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is attributed to two papers:

- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. [HYPERLINK "<https://doi.org/10.1126/sciadv.aao3354>"]

and

- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308-13313. [HYPERLINK "<https://doi.org/10.1073/pnas.1921628117>"]

Diffenbaugh et al. presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not "robust" evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something which even the IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using 3 GCMs, found "A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically." However, they noted large differences among the three models in their simulated precipitation changes. Also, 2 of the 3 models failed to yield detection for Rx5Day for the North America mean. Finally, the authors used Total Least Squares, an estimation method known to overstate signal detection results (CWG Section 8.3.2). Here again this is not "robust" evidence, it is suggestive but other studies have found natural variability predominant. Both cited references utilized the implausible RCP8.5 scenario and began their "historical" observational records only in 1961.

4 RELIANCE ON *Ad Hoc* TIME SCALES FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need to be careful regarding the choice of time scale when making claims about trends in extreme weather. We gave examples from analysis of river flooding (6.1), heatwaves (6.3) and extreme precipitation (6.4) to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here we elaborate on these examples to illustrate a general point that NCA5 made inconsistent and *ad hoc* choices about time scales of analysis, weakening the validity of their conclusions.

4.1 Average and Extreme Precipitation

McKittrick and Christy (2019)⁶ showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s depending on location or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017)).

In CWG Section 6.4 we presented analysis of updated data for the same locations and many more besides, in all cases finding considerable regional heterogeneity and lack of robustness of trends to use of long samples.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion, instead it refers to changes “since the 1950s” which we take to mean 1950 onwards though NCA5 Fig. 2.8 suggests 1958 as the start date. For the present report we have extended the analysis even further now to include 141 stations across the US in the Pacific Coast, Southwest, Midwest, Northeast and Southeast regions. We provide details in the Appendix; here we note merely that once again it is possible to find trends that support the NCA5 position, but they are not robust to selecting longer or shorter time scales of analysis. Data from 1950 to 2024 yields many indications of increased average and extreme precipitation at individual stations and region-wide averages. But when using the entire data set (back to the 1890s or earlier depending on location) or the later subset (1980 to 2024) the trends become smaller, in many cases they become statistically insignificant, and occasionally they change sign. Only in the Northeast region are the post-1950 trends robust to focusing on the post-1980 interval.

Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

“Rainfall is becoming more extreme”

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity. The largest increase in the number of extreme precipitation days (defined as the top 1% of heaviest precipitation events) has occurred over the Northeast (an increase of around 60%) and Midwest (around 45%), along with increases of more than 10% in their annual and 5-year maximum amount

⁶ McKittrick, R., and J.R. Christy (2019). Assessing changes in US regional precipitation on multiple time scales. *Journal of Hydrology*, 578, 124074. [[HYPERLINK "https://doi.org/10.1016/j.jhydrol.2019.124074"](https://doi.org/10.1016/j.jhydrol.2019.124074)]

(Figure 2.8). These changes have contributed to increases in river and stream flooding in these regions. The increase in frequency and intensity of precipitation extremes is evident across a broad range of event durations (from 1 to 30 days) and return intervals (1 to 20 years), particularly east of the Rocky Mountains.

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US. Paleoclimate records derived from tree-ring growth provide evidence that summer moisture has increased over the past century in parts of New England, the central-eastern US, and the northern Mississippi River valley.

The following is a more accurate summary of what U.S. data show.

There are regionally-heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution to anthropogenic warming difficult.

Along the Pacific coast very few stations (1 or 2 out of 29) exhibit significant trends on any time scale in any metric and the region-wide trends are insignificant. In the Southeast region about 5 out of 24 stations exhibit positive trends in average and extreme precipitation metrics and the regional trends are likewise significant, but only on samples beginning in 1950. When the sample starts in 1873 or 1980 the trends weaken and become mostly insignificant. In the Midwest region nearly half the stations exhibit positive and significant trends in average precipitation since 1893 (23/61) and 1950 (28/61) but the trends weaken after 1980: only 6/61 locations are significant and the region-wide trend is insignificant. These positive trends reflect the dryness of the 1930's Dust Bowl era. Regional trends in max and 99th percentile exceedances are insignificant post-1893 and -1980 but the latter are positive and significant post-1950.

In the Northeast region 12 out of 27 stations exhibit positive and significant increases in average precipitation post-1888, post-1950 and post-1980 (10/27) and the regional trend is positive and significant in all three intervals. The regional number of 99th percentile exceedances has a positive trend post-1950 and post-1980 but not post-1888. The significant positive trends post-1980 are concentrated in NH but are insignificant elsewhere.

Consequently, precipitation in the U.S. exhibits considerable regional and temporal variability. Relatively more places became wetter than drier. In the Midwest and Northeast the general pattern since 1950 favors increased precipitation depending on the location, although trends since 1980 have not tended to be statistically significant.

4.2 Heatwaves

- details; NCA4 used entire 20th century while NCA5 looked at post-1960 interval

5 INADEQUATE TRACEABLE ACCOUNTS

- details

~~6 OVERCONFIDENCE WHEN STATING CONCLUSIONS~~

- details

~~76 RELIANCE~~OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to “project major trends for the subsequent 25 to 100 years,” the NCA relies on projections of future climate change ~~are based on~~ driven by estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.”

NCA5 makes the following ~~statements~~ observations about ~~future~~ the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue ~~The the~~ NCA5 otherwise ignored a the problem large body of literature (summarized in section xxx of the DOE Report) that shows the 2.5 and the 7.0 scenarios to be implausible, and advises against using them for policy-making purposes. In 2021, UN Climate Negotiators (COP) stopped using scenarios above 4.5. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.”

Even in the context of NCA5 being advised to assess the full range of scenarios available, a keyword search of the NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, 10 figures only included the 8.5 scenarios: 5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13.

The problem of relying on extreme scenarios is particularly acute for sea level rise projections. The sea level rise scenarios used in the NCA5 do not relate directly to the SSP emissions scenarios, but to specified amounts of sea level rise by 2100, whereby Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet). (Table 4 of Guide to Using this Report).

Considering only projections representing processes in whose quantification there is at least medium confidence, the IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m (for the 5th–95th percentile range), for all scenarios ranging from RCP2.6 to RCP8.5. The IPCC AR6 cites values as high as 2.4 m at the upper end of the 95th percentile range for RCP8.5, if estimates include the hypothesized Marine Ice Cliff Instability (low confidence). The corresponding

The range of sea level rise scenarios considered by the NCA5 includes Intermediate-High (from 1.5 m) and High (to 2.0 m) values that associated with the implausible extreme emissions scenario RCP8.5 and processes in which there is low confidence in understanding. The NCA5 neglects to include plausible lower scenarios, such as 0.2 m cited by the IPCC, that which also corresponds to the average rate of sea level rise over the past century.

With regards to actual predictions of sea level rise, Chapter 9 of the NCA states: "Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2)." These values of sea level rise encompass the Intermediate scenario to values slightly higher than the High scenario from Table 4 << which Table 4.7.

Global sea level rise projections to 2050 relative to a 2000 baseline can be evaluated with respect to the observed global sea level rise from 2000-2024, which is approximately 3.39 inches (0.28 feet). [HYPERLINK "https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level"] Hence it is inferred that NCA5 is projecting values of sea level rise between 2025 and 2050 that are 3.5 to 5.8 times the rate observed during 2000-2024.

Chapter 9 further states: "Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches." This analysis accounts for the observed sea level rise between 2000 and 2020. << But they say it's relative to 2020.

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With regards to confidence levels, NCA5 Chapter 9 Traceable Accounts states: "There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050" Neither the statement nor the context in the paragraph *does not* distinguishes as to whether this refers to global sea level rise, or US average sea level rise, although it is inferred to refer to global sea level rise.

In summary, the NCA5 presents future sea level rise scenarios that are not directly relatable either to SSP/RCP emissions scenarios or global warming levels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes for which there is low confidence. Projections to 2050 require rates of sea level rise during from 2025 through to 2050 that are more than three times the

rate observed during 2020-2024. Further, the NCA5 ascribes *high confidence* to these sea level rise projections.

The inclusion, and even the focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

87 BIASED SELECTION OF REFERENCES

-details

98 SUMMARY: EVALUATING EVALUATION OF THE NCA5

9.18.1 Pertinent aspects when evaluating in light of statutory requirements

- not our remit to make a ruling but here are aspects to consider in light of statutory requirements

9.18.2 Evaluation from the perspective of expert users of the report

- we have deep knowledge of the topics surveyed by the NCA5 authors
- we do not have confidence that the report was balanced and comprehensive
- we can point to many specific instances in which the report did not exhibit an appropriate level of quality or integrity as a scientific document
- we have reason to believe the whole process, from author selection to handling of expert reviews, was biased towards reinforcing foregone conclusions and alarmist messaging

9.18.3 Evaluation from the perspective of citizens interested in good policymaking

- Public concerns about climate change are valid, as are concerns about cost of living, economic growth, employment, etc.
- We share the general concern that elected officials and those who serve them have the best information available when making important decisions around energy and climate policy
- NCA5 was a missed opportunity: it could have been a valuable input to that process but it did not turn out that way
- consequently its usage is unlikely to lead to better decisions and would more likely increase the error rate in policy formation and we recommend it not be used for policymaking purposes.

APPENDIX 1: Seth's letter on statutory requirements for NCA5

APPENDIX 2: Analysis of 141 U.S. Longterm Daily Precipitation Records.

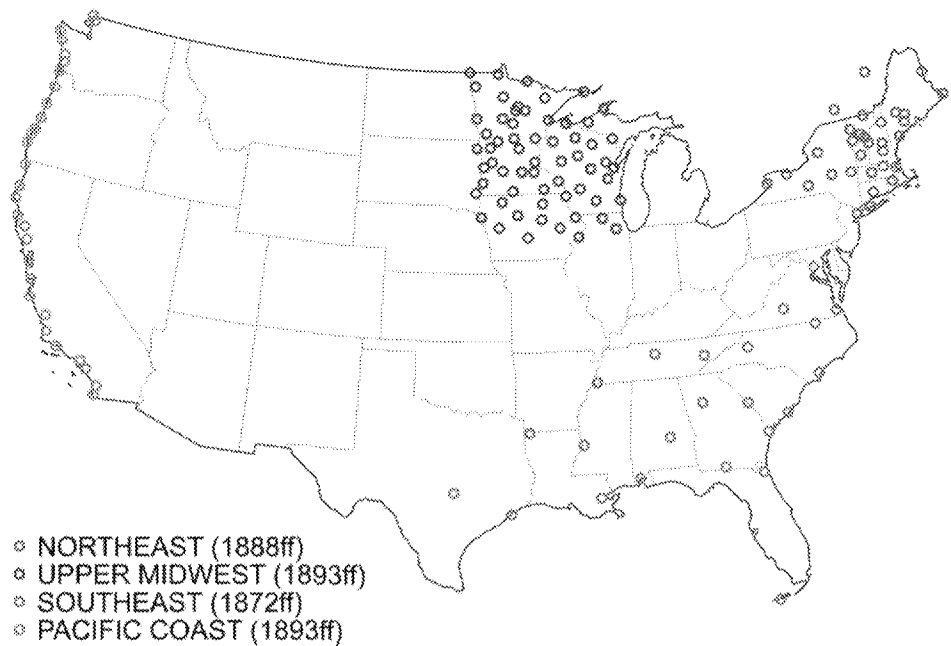


Figure. Stations used in the following analyses.

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure
Column 2: Number of stations in that region
Column 3: Count of stations exhibiting a significant positive trend
Column 3: Count of stations exhibiting a significant negative trend
Column 5: Characteristic of region-wide trend

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)

Number of 99 th pct exceedances	29	1	0	(-)
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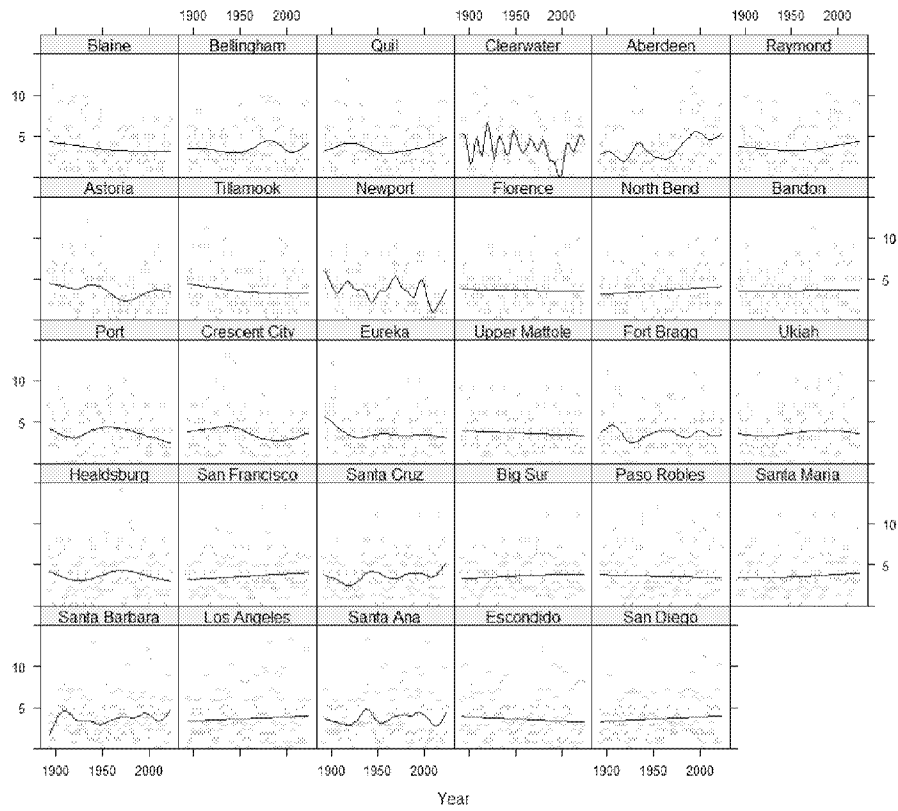
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

Annual No. 99th Percentile Exceedances PC 1893-2024



SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

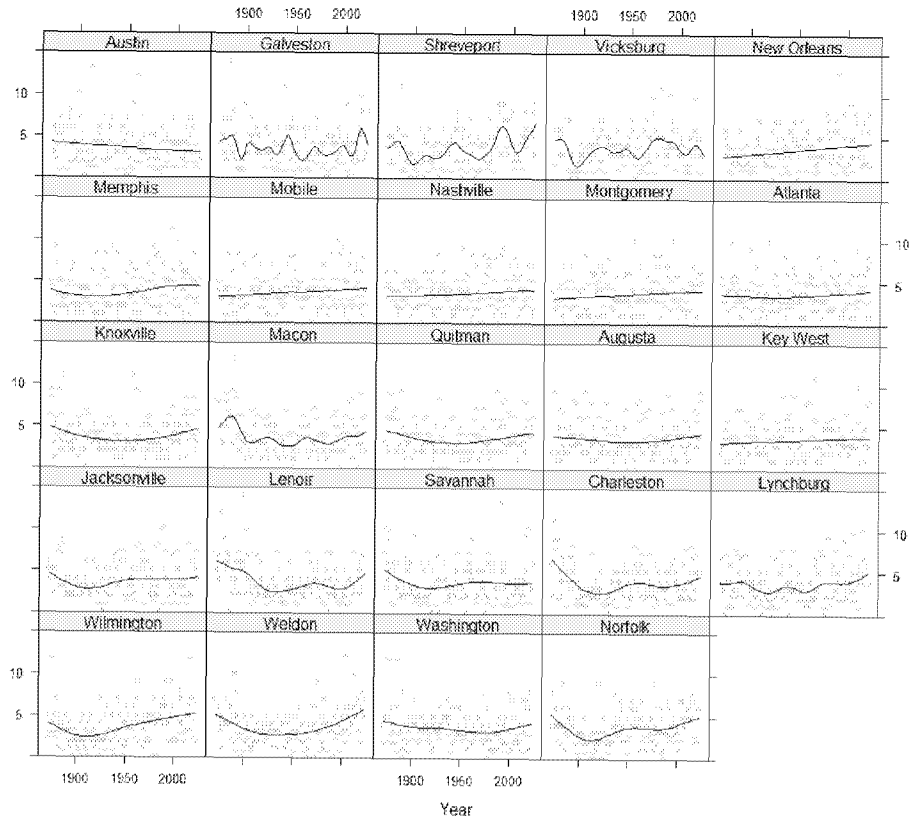
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

Annual No. 99th Percentile Exceedances SE 1873-2024



MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

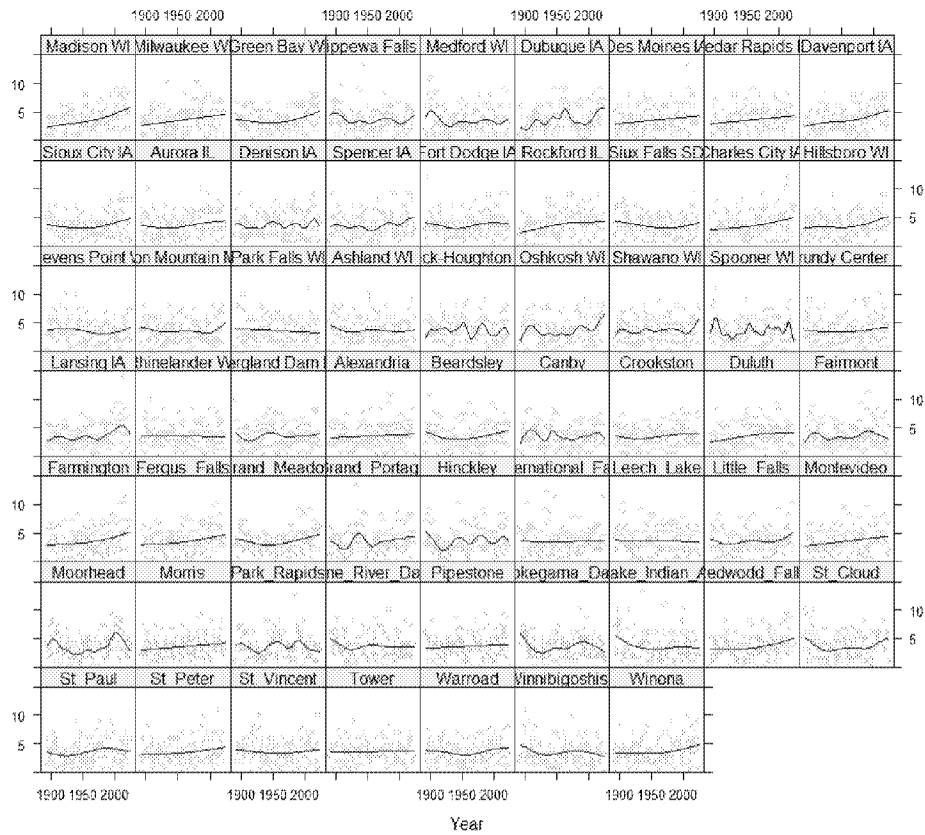
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

Annual No. 99th Percentile Exceedances MW 1893-2024



NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

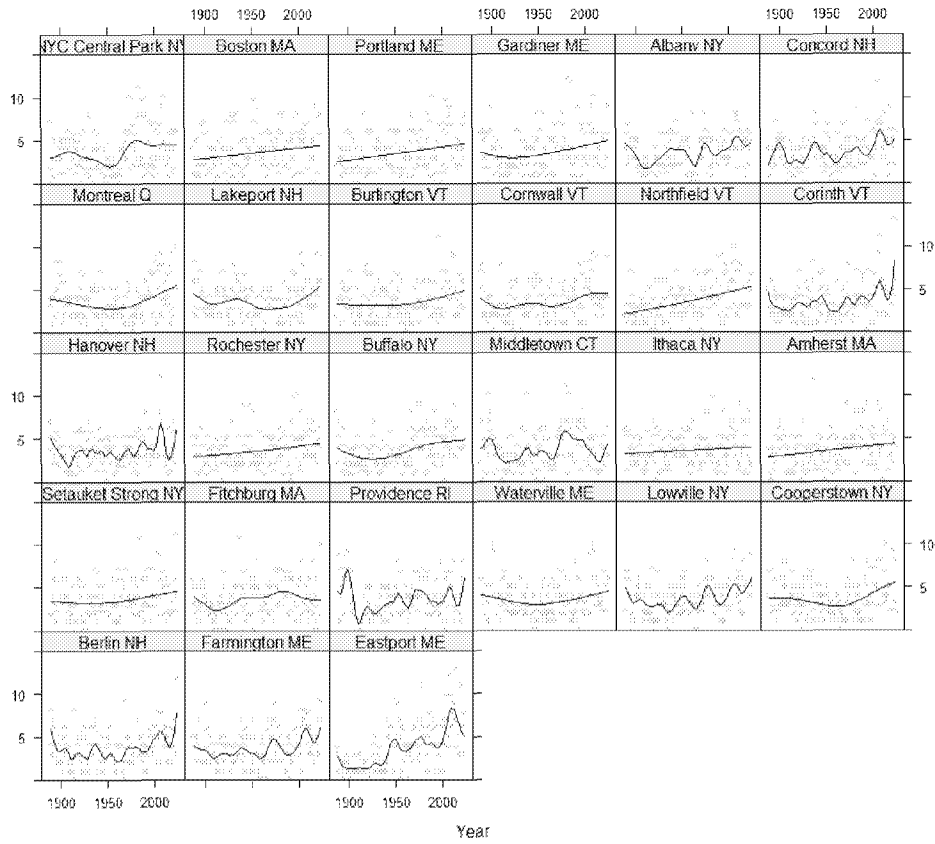
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

Annual No. 99th Percentile Exceedances NE 1888-2024



Review of the Fifth National Climate Assessment

[TOC \o "1-3" \h \z \u]

EXECUTIVE SUMMARY

This report critically evaluates the Fifth National Climate Assessment (NCA5), finding it an inadequate basis for climate and energy policies. A detailed review of the foundational chapters on climate science raises several key concerns:

Scientific Integrity

- An advocacy tone, particularly in the Overview chapter, inconsistent with scientific objectivity
- An endemic overconfidence when stating conclusions, including inflated certainty levels and overstatement of findings from underlying sources

Flawed methodology

- Use of *ad hoc* time scales for trend analyses in areas such as precipitation and heatwaves
- An overemphasis on extreme scenarios for future emissions
- Inadequate traceable accounts to support key conclusions

Deficient Review Process

- A review by the National Academy of Sciences, Engineering, and Medicine (NASEM) failed to challenge some fundamental flaws in NCA5
- The NCA5 authors failed to adopt some improvements recommended by NASEM

The report shows NCA5 to be a biased and incomplete picture of climate science that skews toward excessive climate risk. Consequently, NCA5 should not be used as basis for climate and energy policies.

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1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix 1) that we assess the suitability of the Fifth National Climate Assessment (NCA5 2023) for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, the National Academies (NASEM) review of the Third Order Draft, and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, the IPCC and other organizations, as writers, reviewers and study leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science as of its publication in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted "CWG25"). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

To support our finding, the following sections of this chapter provide some background on the National Climate Assessments and the standards by which we have assessed NCA5. Chapters 2 through 6 detail important ways in which NCA5 fails to meet those standards. Chapter 7 then follows with an assessment of the NASEM review. Finally, Chapter 8 summarizes our evaluation of NCA5.

1.2 About the National Climate Assessments

The [[HYPERLINK "https://www.globalchange.gov/"](https://www.globalchange.gov/)] (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.

- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was a further expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on "Climate Action" and policy recommendations with a social justice emphasis. NCA5's self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA's statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (Section 1.4 below offers an example). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

In Appendix 2 we include a letter of guidance from the Office of General Counsel, U.S. Department of Energy, summarizing the statutory requirements governing USGCRP work products in general and NCA products in particular.

We can summarize the standards applicable to the NCA as follows:

- details.

Beyond the statutory requirements we draw attention to two other pertinent standards. President Trump's executive order of May 23, 2025, "[[HYPERLINK "https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/"](https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/)]" enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some scientists have found them controversial (Dellawalla et al. 2025).

There are other desiderata for scientific reports that will be highly influential on climate policymaking. Among them are statements about the strength of climate knowledge. The IPCC's approach is based on judgment of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include (Arven 2017):

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns

Good climate and energy policies balance the risks and benefits of a changing climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.

In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to "save the planet." Further, the field of climate science has been politicized by NetZero mandates. It is then not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.

In 1980, then-President of the National Academy of Sciences Philip Handler identified the problem in an editorial (Handler 1980) that resonates eerily four decades later:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

1.4 When Peer Review Fails

Peer review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, during the open review phases of early NCA drafts reviewers are volunteers who self-select what parts of the report to read, whereas the editors of academic journals editors recruit reviewers with relevant expertise and assign them to specific papers. As a result, there is no guarantee at that stage that any particular section of an NCA report was reviewed by anyone, ~~WHAT ABOUT THE NASEM REVIEW?~~ let alone by someone with a perspective that differs from the authors. In fact, many potential reviewers have given up over the years because their input has systematically been ignored. The introduction of a NASEM review stage is at best a partial remedy for this. However, Second, NCA authors have near complete authority whether to accept or reject review comments. By contrast, the Editor of an academic journal mandates the author to respond, and the reviewer and Editor assess its adequacy. And third, Finally, the work of an NCA chapter author team is guaranteed to be published, whereas academic journals routinely reject papers that do not pass review.

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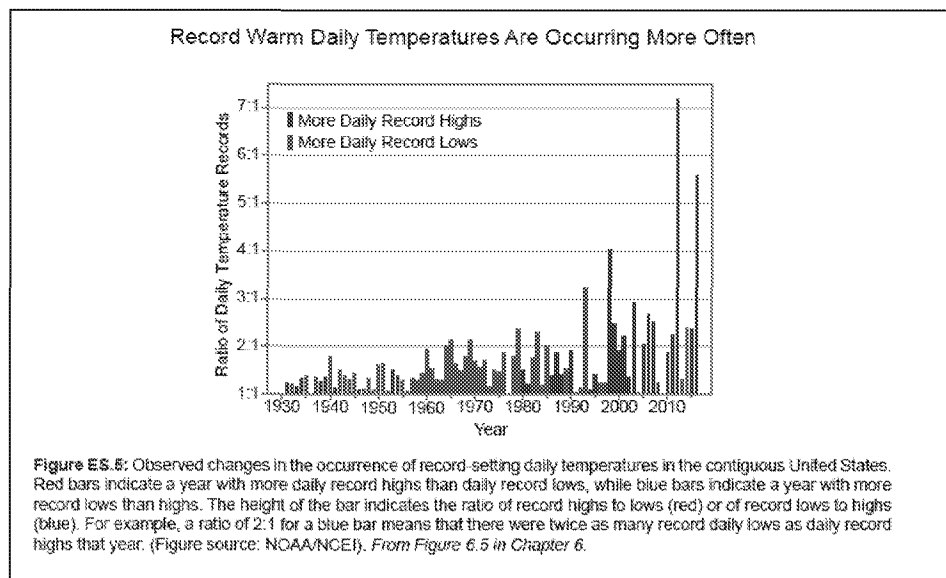
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These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were "peer reviewed". But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

As shown in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Considering cold and hot extremes together the U.S. the U.S. climate has become more moderate over time. NCA4's Part I ~~{[HYPERLINK "https://science2017.globalchange.gov/"]}~~, CCSP) says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

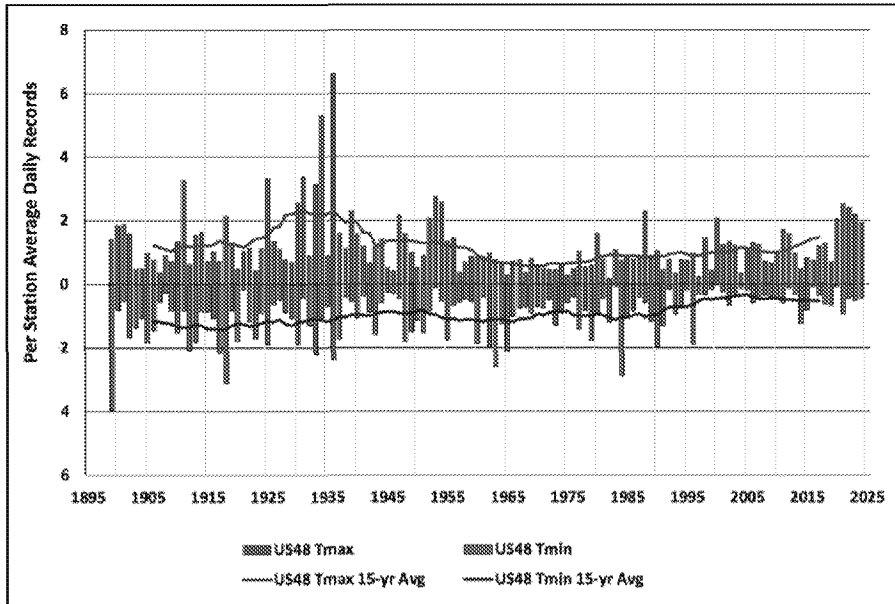
and offers this figure in support:



The figure appears to validate the claim that record warm daily temperatures are occurring more often. But the underlying data do not. Rather, they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as supported by Figure 6.4 deep within the CSSR itself (reproduced in our Section 4.2 below).

Figure ES.5 does not even show what its title implies, as it displays not simple counts of cold and warm extreme events, but rather ratios of the two counts. In fact, both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes increased. By graphing the ratio instead of counts, NCA4 creates a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis of the data – defining each record as the singular extreme in the sample interval, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the heat records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio of heat to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of NCA4 Figure ES.5.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3.

The National Academies' expert review panel [[HYPERLINK "https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report"](https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report)] the discussion of temperature extremes in a [[HYPERLINK "https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf"](https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf)] of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) [[HYPERLINK "https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf"](https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf)] to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]... and a new figure was added on changes in record high and low temperatures

The “new figure” referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies’ panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn’t have survived to publication. And the figure’s problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

With this background we now present our critique of NCA5.

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2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

NCA5 Chapter 1, "Overview", holds a prominent place in the Report since it summarizes the entire report and is the only section that many will read. Although the later chapters of NCA5 contain much sound scholarly content, Chapter 1 is marred by an activist tone and language that aggressively promotes mitigation policies. As such, this chapter adds an imprimatur of scientific authority to oversimplified declarations of opinion about public policy. Many examples can be cited; here we note a few that are particularly egregious.

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Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic, that all warming is bad and causes economic damage, and that warming intensifies extreme weather. Such sweeping generalizations go well beyond what science has or can establish. The statement also refers to growing risks without saying whether they were large to begin with-- a small risk that grows may still be a small risk, and a large risk may be only incrementally worsened. A scientifically-sound version of this paragraph would instead say something like the following:

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The Earth is warming because of a combination of natural and anthropogenic influences. This warming will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. Some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases might slow the warming although such policies have proven to be costly and disruptive, so any climate actions to be weighed against the potential benefits.

On the next page the Overview states:

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Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits..."

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms; in fact, NCA5 Chapter 19 acknowledges that there will also be benefits. Nor is

climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers.

Pages 8 and 9 of the Overview promote renewable energy options by noting, correctly, that the leveled costs of wind/solar generation have fallen sharply since 2010, and so offers this rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) significantly increases the cost of electricity. Further, there are yet unmet synchronization challenges in transmission grids with heavy penetration of wind and solar power. Here again it is advisory malpractice not to acknowledge these facts.

Page 14 of the Overview presents future emission scenarios with the following description: "Climate modeling experts develop global climate projections for a range of plausible futures." The word "plausible" is applied to all of the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The Figure does not compare observed emissions with previous projections nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as "plausible" the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline "business-as-usual" future.

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Page 17 of the Overview introduces the discussion of risks from extreme weather events by saying "Harmful impacts from more frequent and severe extremes are increasing across the country." This creates the impression that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the value of assets at risk it then invokes the NOAA Billion Dollar Dataset as evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product (Pielke Jr. 2024, 2025). Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends.

Page 23 of the Overview states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote alarm, but also the ineffectiveness of the review process in not ensuring such statements are removed.

The tone of the Overview chapter hints at the priorities that governed the writing of the entire report. Word counts of the full report are another crude indicator of those priorities. Table 1 lists word occurrences in NCA5 compared to occurrences in the CWG25 report. The contrasts are only partly attributable to differences in length, they primarily arise from different priorities of the author teams.

Term	NCA5	CWG25
Forcing	111	85
Uncertainty	384	21
Watts, W/m ²	31	16
Culture/culturally	854	0
Equity/equitable	572	0
Indigenous	890	0
Sustainable	295	1
Racism/racial	153	0

Table 1: Word occurrences in NCA5 and CWG25 reports.

3—OVERCONFIDENCE WHEN STATING CONCLUSIONS

3

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3.1 Inflated certainty levels

Overconfidence in stating conclusions is an endemic problem in NCA5. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of NCA5 states that

confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.

and Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high: Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus

High: Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus

Medium: Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.

Low: Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. The following example illustrates with respect to the conclusion regarding anthropogenic influence on climate change, arguably one of the most important scientific statements of the report:

Key Message 3.1 Traceable Account states:

There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.

while the corresponding statements from IPCC AR5 and AR6 are

AR5: It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together." (IPCC, 2013)

AR6: The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, AR5 refers to "*more than half* of the observed warming" and AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

Quite separately we note that the attribution of various changes to "climate change" is misleadingly ambiguous. Because NCA5's Glossary defines "climate change" as a change in climate for any reason, the statement is a tautology and so the attribution is superfluous. But because the popular perception of climate change is anthropogenic, its gratuitous inclusion effectively attributes the changes to greenhouse gas emissions

3.2 Overstating findings in underlying sources

Although we did not do a detailed audit of NCA5's use of source material, spot checks turned up evidence of a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in some areas and attributes it to human caused climate change:

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Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

Note that this is a non-standard metric; we will discuss NCA5's inconsistent choices of time scales of analysis below. The claims were attributed to the following paper:

- Knutson, Thomas and Fanrong Zeng (2018) "Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends" *Journal of Climate* 31(12) [[HYPERLINK "https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml"](https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml)]

But Knutson and Zeng did not say these things. They examined linear trends over 1901 – 2010, 1951 – 2010 and 1981 – 2010. They did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 – 1960, if only because their study was published in 2018. For 1981-2010, they noted stronger trends in some areas but cautioned that such changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States:

Observed annual precipitation trends over the recent 30-yr period 1981–2010 ([[HYPERLINK "https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml" \l "fig5" \] \]\) have generally stronger magnitudes \(in mm yr⁻¹ decade⁻¹\) than observed trends for 1901–2010 or 1951–2010. This is as expected since trends over a shorter period have stronger potential for occurrence of pronounced temporary trends due to internal variability alone. Only 9% of the analyzed area has detectable and attributable anthropogenic influence \(categories –3, –2, +2, +3\), which represents less than one-third of the fractional areal coverage of such trends for 1901–2010 \(29%\). ... Eight percent of the analyzed area has attributable anthropogenic *increases* \(categories +2, +3\), including parts of eastern Europe, northern Asia, northern Australia/Maritime Continent, and tropical Africa.](https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml)

As another example of overstating findings, NCA5's Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is allegedly attributed to two papers:

- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. [[HYPERLINK "https://doi.org/10.1126/sciadv.aao3354"](https://doi.org/10.1126/sciadv.aao3354)]
- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308-13313. [[HYPERLINK "https://doi.org/10.1073/pnas.1921628117"](https://doi.org/10.1073/pnas.1921628117)]

Diffenbaugh *et al.* presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not “robust” evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something that even IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using three GCMs, found

A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically.

However, they noted large differences among the three models in their simulated precipitation changes. Also, two of the three models failed to yield attribution for 5-day events for the North America mean. In other words the models disagreed on whether the observed changes were due to anthropogenic activity. Both cited references utilized the implausible RCP8.5 scenario and began their “historical” observational records only in 1961. Here again this is not “robust” evidence, it is merely suggestive, particularly since other studies have found natural variability predominant.

3.3 Technical example: Emergent constraints

Some of the overconfidence expressed by NCA5 arises by omitting discussion of counterevidence in the peer reviewed literature. An example is the topic of “emergent constraints”. Chapter 3 page 17 invokes this concept to support its claim that key uncertainties have been reduced:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as “emergent constraints.” The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie GCM behavior to climate observations in hopes of generating insight into real-world equilibrium climate sensitivity to a doubling of carbon dioxide (ECS). Climate models exhibit a wide range of ECS values. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could examine whether the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

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A problem in the emergent constraint literature is that there has been a proliferation of proposed correlations with little physical motivation. Many emergent constraints patterned on CMIP5 models failed to work on CMIP6 models (Schlund *et al.* 2020). In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the Earth climate system.

The result was that emergent constraints estimated from CMIP5 models widened the range of estimated ECS values when applied to CMIP6 models.

Schlund *et al.* summarized the problem as follows [**boldface** used for emphasis]

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great “advance” that reduced uncertainty.

4 RELIANCE ON *Ad Hoc* TIME SCALES FOR TREND ANALYSIS

In CWG25 Chapter 6 we discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We provided examples from analysis of river flooding, heatwaves, and extreme precipitation to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here we elaborate on these examples to illustrate the general point that NCA5 made inconsistent and *ad hoc* choices about time scales of analysis, weakening the validity of their conclusions.

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McKittrick and Christy (2019) showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s, depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017). In CWG25 Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

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4.1 Average and Extreme Precipitation

McKittrick and Christy (2019) showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s, depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017). In CWG25 Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion; instead it refers to changes “since the 1950s”; NCA5 Figure 2.8 suggests 1958 as might be the intended start date. Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

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In addition to our concerns that inferences about trends are contingent on choice of time scale, we cannot reproduce the finding that positive trends are observed in extreme precipitation across all CONUS regions. For the present report we have extended the data used in CWG25 (McKittrick and Christy 2025) analysis even further to include 141 stations across the US in the Pacific Coast, Midwest, Northeast and Southeast regions (Christy 2025). We provide details in Appendix 3; here we note merely that once again, many post-1950 trends are positive but statistically insignificant depending on the measure of extreme precipitation. It is possible to find location trends that support the NCA5 position, such as the Southeast post-1950, but these results are not robust to selecting longer or shorter time scales of analysis nor do they generalize across all regions. Data from 1950 to 2024 yields many indications of increased average and extreme precipitation at individual stations and region-wide averages. But when using the entire data set (back to the 1890s or earlier, depending on location) or the later subset (1980 to 2024) the trends become smaller, in many cases they become statistically insignificant, and occasionally they even change sign. Only in the Northeast region are the post-1950 trends robust to focusing on trends during the post-1980 interval.

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The following is a more accurate summary of what U.S. data show.

There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution of changes in precipitation to anthropogenic warming difficult.

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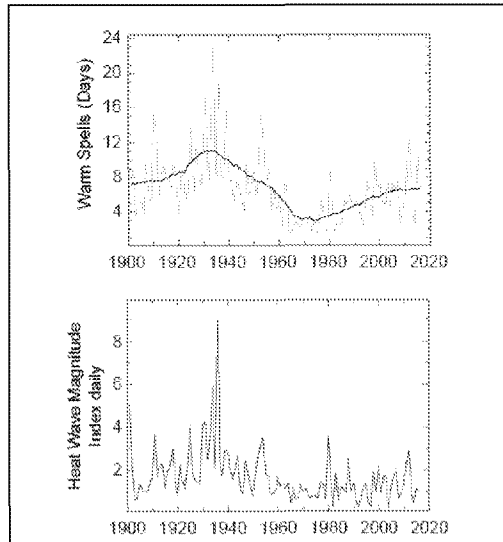
4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the entire 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies:

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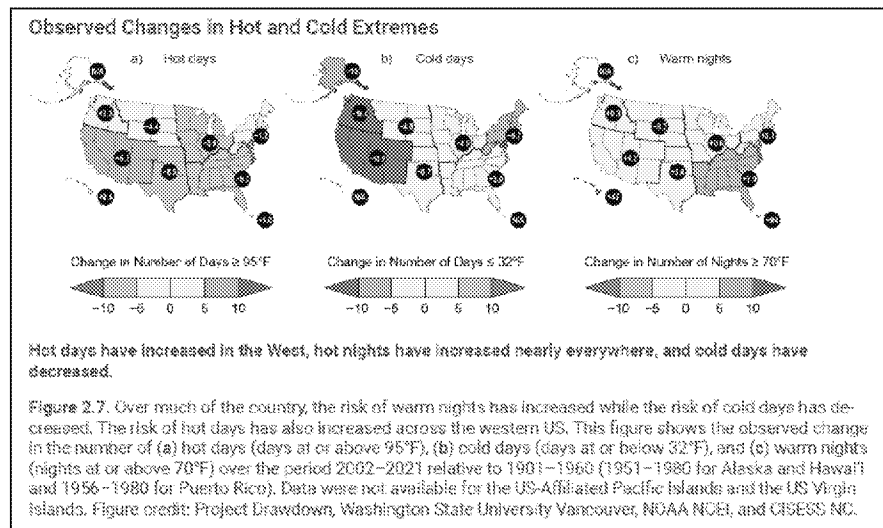
[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s.
(NCA4 pp. 190-191)



U.S. Heat waves since 1900. Source: NCA4 Figure 6.4

Contrast this careful and factual language with NCA5 Key Message 2.2: “Extreme Events Are Becoming More Frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 (reproduced below) which shows the number of hot days, cold days and warm nights (respectively in panels a—c) over the period 2002-2021 compared to 1901-1960. [Presumably these are annual counts, although not stated in the caption.]



Close inspection shows that this figure contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of NCA4. Notwithstanding Key Message 2.2 the leftmost panel in Figure 2.7 above shows that over most of CONUS the number of extreme heat days has decreased in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted as it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 chapter 2 elaborates on Key Message 2.2 by saying (page 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But while it mentions the increase in hot days in the west it fails to mention WHAT DECLINE the decline-decrease elsewhere everywhere east of the Rockies. Instead, it says On the next page (page 17) it raises the comparison to the 1930s then switches to discussing global counts: THIS POINT IS UNCLEAR

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

The reference to a global trend seems to be an attempt to tie heatwaves to anthropogenic climate change. But the obvious question, unaddressed by NCA5, is why one region follows the global pattern of increasing heatwaves if WHAT?? holds for only part of the U.S. while most of the country is trending in the opposite direction. These issues are addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by natural variability than by the small anthropogenic forcing. The analysis in CWG25 shows that for both (a)

hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is no hotter than a century ago ~~in the U.S.~~ Thus, the NCA5 claim that “multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal and spatial domains to encompass all available data (Chapter 6 and Figure 6.3.6 of CWG25).

NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG2025 Section 8.6.1 discussed this event in detail, reviewing the multiple peer reviewed studies that explained the unusual meteorological context was unrelated to human-caused climate change, a point omitted from the NCA5 discussion.

NCA5 finally addresses the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator ([HYPERLINK "https://www".globalchange.gov/indicators/heat-waves]) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed ~~this issue~~ ~~WHAT ISSUE~~ part of NCA5 in CWG25 Section 6.3. The figure referenced by NCA5 uses an *ad hoc* definition of heat wave, namely two consecutive days with minimum nighttime temperatures above the 85th percentile, and an *ad hoc* time scale which begins in the 1960s, the coldest decade in the last century, thus suppressing any comparison to the 1930s. Further, nighttime temperatures in urban areas have increased faster than daytime temperatures (which NCA5 acknowledges), but this is a signature of urban heat islands and not a good metric of climate change. CWG25 noted as well that the occurrence of hot days ($\geq 95^{\circ}\text{F}$) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

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5 INADEQUATE TRACEABLE ACCOUNTS

NCA3 began the practice of including a section on Traceable Accounts at the end of each chapter. This is the description from NCA5:

Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team's expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.

The Traceable Accounts for each Key Message includes the following sections:

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- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts could in principle address the statutory requirement that the NCA discuss scientific uncertainties. They could also help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5's Chapters 2 and 3 (the only chapters investigated here) are uneven, often superficial and noninformative.

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An example of a deficient Traceable Account is NCA5's Key Message 2.2: "Extreme Events are Becoming More Frequent and Severe". The "Description of the Evidence Base" offers two paragraphs, the first summarizing the findings and the second generically describing the types of data that can be used for storms. "Major Uncertainties and Research Gaps" focuses on the uneven distribution across U.S. populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data apart from reanalysis products.

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But the most astonishing deficiency is in the "Description of Confidence and Likelihood." One of the statements in Key Message 2.2 is:

Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence).

The Description of Confidence and Likelihood includes the following statement:

Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.

No reference to journal publications or a specific data set is made in the Chapter regarding hurricane induced precipitation or storm surge to support this *high confidence* conclusion.

The Traceable Accounts for the various Key Findings of Chapter 3 have some substantial inconsistencies. Consider

Key Message 3-1: Human activities have caused global warming.

Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

The Uncertainties section addresses only uncertainties in radiative forcing by greenhouse gases. In contrast, the Traceability Analysis of Key Message 3-4 ("Humans Are Changing Earth System Processes") is arguably the most scientifically credible text in the entire Chapter, raises the problem that relatively little is known about the role of natural variability at the regional scale. From its Description of Evidence Base:

In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals.

And from its Major Uncertainties and Research Gaps:

For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.

These statements are among the most scientifically credible in the entire NCA5 and they directly undercut the confidence assigned to Key Message 3-1.

There is also a generic problem in tracing NCA5's Traceable Accounts. The Front Matter of NCA5 states:

Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.

Upon clicking on the eyeball icon above a particular figure, a "Contact Us" email appears, addressed to the USGCRP. No attempt was made to send a email to elicit the Metadata information, but it is clear that this information is not readily accessible online.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.

6 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to “project major trends for the subsequent 25 to 100 years,” NCA5 relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.” and that same year UN Climate Negotiators (COP) stopped using scenarios above 4.5.

NCA5 makes the following observations about the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue, NCA5 otherwise ignored the problem. A keyword search of NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, 10 NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios.

The problem of relying on extreme scenarios is particularly acute for NCA5’s sea level rise projections. The sea level rise scenarios used in NCA5 do not relate directly to the SSP emissions scenarios, but rather to specified amounts of sea level rise by 2100. Table 4 of NCA5’s “Guide to Using this Report” reproduced below shows that Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet).

Table 4. Descriptive Statistics for Common Sea Level Rise Scenarios from NCA5						
Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2022. ¹⁴						
Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

Table 4 from the Front Matter of NCA5

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Considering only projections representing processes quantified with at least medium confidence, IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m (5th—95th percentile range). Nevertheless, the range of sea level rise scenarios considered by NCA5 extends to 2.0 m. Further, NCA5 fails to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which also corresponds to the average rate of sea level rise over the past century.

Chapter 9 of NCA5 offers the following predictions of sea level rise:

“Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2).”

These values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the [[HYPERLINK "https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level"](https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level)] global sea level rise from 2000–2024, approximately 3.39 inches (0.28 feet). NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000–2024. Chapter 9 further states:

“Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9–13 inches.”

...

“There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050”

In summary, NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios nor to global warming levels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes in which there is low confidence. Projections to 2050 require rates of sea level rise from 2025 to 2050 that are more than triple the rate observed during 2020–2024. Further, NCA5 ascribes *high confidence* to these sea level rise projections.

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More generally, NCA5's inclusion, and even focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 INADEQUATE NASEM REVIEW: TO BE ADDED

I THINK WE SHOULD DELETE THIS CHAPTER, IT ISN'T VERY STRONG

The National Academies of Science, Engineering and Medicine (NASEM) undertook a detailed review of the draft NCA5 (NASEM 2023).² While they raised some of the same concerns that we have articulated herein, their review is superficial overall and appears to be written by authors who share many of the biases of the NCA5 team. There is an inordinate focus on social and policy issues (e.g., every chapter is assessed under the heading "Comments on Equity and Justice"), rather than on the underlying science. In our assessment NASEM failed to apply the serious rigor one would expect. A few extracted comments from it will illustrate. Note that NASEM review comments are included here in blue font for reference.

7.1 Substantive criticisms by NASEM

- summarize the valid points made by NASEM and check the NCA replies

7.2 Failures to challenge NCA5 flaws

NASEM praised Chapter 2, saying:

The chapter [2] meets the requirements of Section 106 of the GCRA.

Yet contrary to the requirements of Section 106, NCA5 Chapter 2 did not adequately discuss natural variability let alone assess the full climate record available for quantifying natural variability. Chapter 2 actually minimizes natural variability by claiming (unsubstantiated) skill in attributing recent extremes to human causes. For example NCA5's Chapter 2 Introduction states,

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"...recent advances in attribution science (KM [HYPERLINK "https://nca2023.globalchange.gov/chapter/3" \l "key-message-3" \t "_blank"]) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."

CWG25 reviews the expert literature demonstrating that this particular event would have happened with or without climate change and that for CONUS, hot extremes are no more frequent now than they were in the past. NASEM did not challenge the unsubstantiated attribution claims in NCA5.

Notwithstanding NASEM's claim that the Chapter complies with Section 106 of the GCRA, it then acknowledged the absence of discussion of natural variability:

² National Academies of Science, Engineering, and Medicine. 2023. *Review of the Draft Fifth National Climate Assessment*. Washington, DC: The National Academies Press. [HYPERLINK "https://doi.org/10.17226/26757"]-

...the discussion and references regarding the role of natural climate variability and its regional differences are missing.

While a nod to natural variability is occasionally found in NCA5, it is usually followed by a “however” to emphasize human influence. One example is the statement just before the claim mentioned above pertaining to extreme event attribution: “There has always been extreme weather, which occurs even in an unchanged climate due to the natural variability of the Earth system. However, recent advances in attribution science (KM [[HYPERLINK "https://nca2023.globalchange.gov/chapter/3"](https://nca2023.globalchange.gov/chapter/3)] \l "key-message-3" \t "_blank"]) mean that the role of climate change in some extreme events can now be quantified in real time...”

We pointed ~~o~~ ~~REFERENCE THE SPECIFIC SECTION OF THIS REPORT~~ out (Section 4.2) that the evidence regarding heatwaves directly contradicts Key Message 2.2. NASEM did not mention this, instead it focused on a somewhat esoteric issue of terminology:

“Extreme Events Are Becoming More Frequent and Severe.”
Key Message 2.2 is another generally well written key message. However, while the title of this key message includes the word “risk,” the key message is exclusively about hazard. The Committee suggests rewriting the key message title to more accurately reflect the discussion on hazards.

The NASEM review appears to accept NCA5’s use of short data records because it makes no critical remarks about the failure to assess long time series, except for its observation that the use of short records makes the omission of natural variability that much more of a problem:

It is also important to point out that the influence of natural climate variability becomes particularly strong when the climate trend is computed based on short periods of time or small geographic areas.

This comment was largely ignored in the NCA5 final text.

In sum, while the NASEM review might bestow the Academies’ imprimatur on the NCA5 report, it does not necessarily add to its quality for two reasons. As we have demonstrated, the NASEM review falls short in rigor and completeness. And second, the NCA authors are not obligated to follow the NASEM recommendations in crafting their final product.

8 SUMMARY EVALUATION OF NCA5

CHAPTER NEEDS A COMPLETE REWRITE

The most straightforward evaluation of NCA5 is through its statutory requirements. While it is not within our purview to make definitive rulings on compliance, we believe there are several important aspects to consider when evaluating NCA5 against its statutory requirements. Add text per Seth's letter ...

~~Our expertise in climate science, the foundational area covered by NCA5, allows a different perspective, one that finds the coverage unbalanced and selective. Our review has identified numerous instances where NCA5 falls short of the quality and integrity expected of scientific document of this importance. Furthermore, our examination suggests that the entire process—from the selection of contributing authors to the handling of expert reviews—appears to have been systematically biased toward reinforcing predetermined conclusions and amplifying alarmist messaging rather than presenting a balanced scientific assessment. In short, NCA5 was written to persuade, not inform.~~

~~A third perspective for evaluating NCA5 is that of citizens interested in good policymaking. The changing climate is a legitimate public concern, as are concerns about cost of living, economic growth, employment opportunities, and other socioeconomic factors. We share the widespread belief that elected officials should have access to the highest quality information when crafting energy and climate policy decisions that must balance multiple concerns. From this perspective, NCA5 is a missed opportunity. What could have been a valuable contribution to informed tradeoffs instead became a misleading advocacy document that corrupts the policymaking process.~~

9 REFERENCES

- Aven, Terje (2017) "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices," *Reliability Engineering & System Safety* 167 (November 2017): 42–48 [[HYPERLINK](https://www.sciencedirect.com/science/article/pii/S0951832016306950) "https://www.sciencedirect.com/science/article/pii/S0951832016306950"]
- Climate Working Group (2025) Impacts of Carbon Dioxide Emissions on the U.S. Climate. Washington DC: Department of Energy, May 27, 2025.
- Dellawalla, Colette, Victor Ambrose, Carl Bergstrom *et al.* (2025) "Trump's new 'gold standard' rule will destroy American science as we know it." *The Guardian* May 29, 2025 [[HYPERLINK](https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science) "https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science"]
- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. <https://doi.org/10.1126/sciadv.aao3354>
- Handler, Philip (1980) Public Doubts About Science. *Science* 208(4448) p. 1093 [[HYPERLINK](https://www.science.org/doi/10.1126/science.208.4448.1093) "https://www.science.org/doi/10.1126/science.208.4448.1093"]
- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308-13313. <https://doi.org/10.1073/pnas.1921628117>
- Knutson, Thomas and Fanrong Zeng (2018) "Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends" *Journal of Climate* 31(12) [[HYPERLINK](https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml) "https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml"]
- Koonin, Steven (2024) *Unsettled: What Climate Science Tells Us, What It Doesn't, and Why It Matters*. ---: ---
- McKittrick, R., and J.R. Christy (2019). Assessing changes in US regional precipitation on multiple time scales. *Journal of Hydrology*, 578, 124074. [[HYPERLINK](https://doi.org/10.1016/j.jhydrol.2019.124074) "https://doi.org/10.1016/j.jhydrol.2019.124074"]
- [McKittrick, R., and J.R. Christy \(2025\). "Data and Code for DoE Report 2025". Mendeley Data, V1, doi: 10.17632/8n9ks93vn7.1](https://doi.org/10.17632/8n9ks93vn7.1)
- National Academies of Sciences, Engineering, and Medicine. 2023. *Review of the Draft Fifth National Climate Assessment*. Washington, DC: The National Academies Press. [[HYPERLINK](https://doi.org/10.17226/26757) "https://doi.org/10.17226/26757"]
- NCA4. (2017). *Climate science special report: Fourth National Climate Assessment, Volume I* (D. J. Wuebbles, D. W. Fahey, and K. A. Hibbard, Eds.). U.S. Global Change Research Program. [[HYPERLINK](https://doi.org/10.7930/J0J964J6) "https://doi.org/10.7930/J0J964J6"]
- NCA5. (2023). *Fifth National Climate Assessment* (A. R. Crimmins et al., Eds.). U.S. Global Change Research Program. [[HYPERLINK](https://doi.org/10.7930/NCA5.2023.CH1) "https://doi.org/10.7930/NCA5.2023.CH1"]
- Pielke Jr., R. (2024). Scientific integrity and U.S. 'billion dollar disasters'. *npj Natural Hazards*, 1, Article 12. [[HYPERLINK](https://www.nature.com/articles/s44304-024-00011-0) "https://www.nature.com/articles/s44304-024-00011-0"]
- Pielke Jr., R. (2025, May 8). RIP NOAA's billion dollar disasters. *The Honest Broker* [Substack]. [[HYPERLINK](https://rogerpielkejr.substack.com/p/rip-noaas-billion-dollar-disasters) "https://rogerpielkejr.substack.com/p/rip-noaas-billion-dollar-disasters"]
- Schlund, Manuel, Axel Lauer, Pierre Gentine, Steven C. Sherwood, and Veronika Eyring (2020) Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6? *Earth System Dynamics* 11 1233-1258 [[HYPERLINK](https://doi.org/10.5194/esd-11-1233-2020) "https://doi.org/10.5194/esd-11-1233-2020"]

APPENDICES

APPENDIX 1: Charge to the review

APPENDIX 2: statutory requirements for NCA5

APPENDIX 3: Analysis of U.S. Reproducibility of NCA5 claim of Long-term Precipitation Record extreme precipitation trends

~~DELETE APPENDIX 3. WE SHOULD NOT BE PRESENTING ORIGINAL ANALYSES IN THIS REPORT~~
~~[I'm not sure we need both the tables and multipanel figures here. Is anyone really going to look at the tables? Perhaps they can be eliminated and just keep the figures?]~~

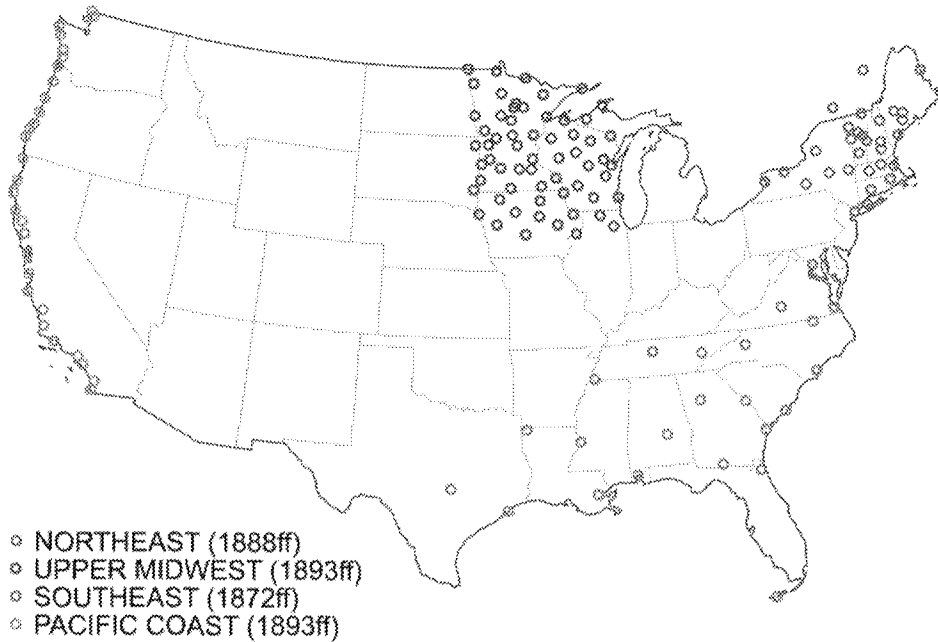


Figure A1: Stations used in the following analyses.

Note: All data are available at Christy (2025). Methods as described in McKittrick and Christy (2019).
code available at McKittrick and Christy (2025).

~~Figure A1: Stations used in the following analyses.~~

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure

Column 2: Number of stations in that region

Column 3: Count of stations exhibiting a significant positive trend

Column 3: Count of stations exhibiting a significant negative trend

Column 5: Characteristic of region-wide trend

|

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)
Number of 99 th pct exceedances	29	1	0	(-)

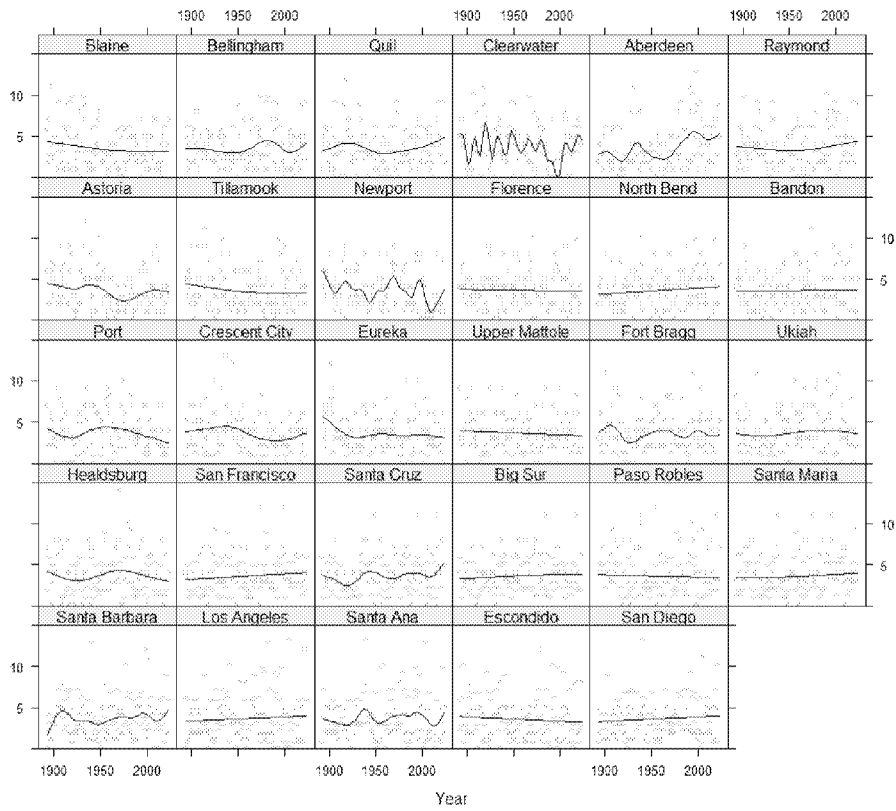
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

Annual No. 99th Percentile Exceedances PC 1893-2024



SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

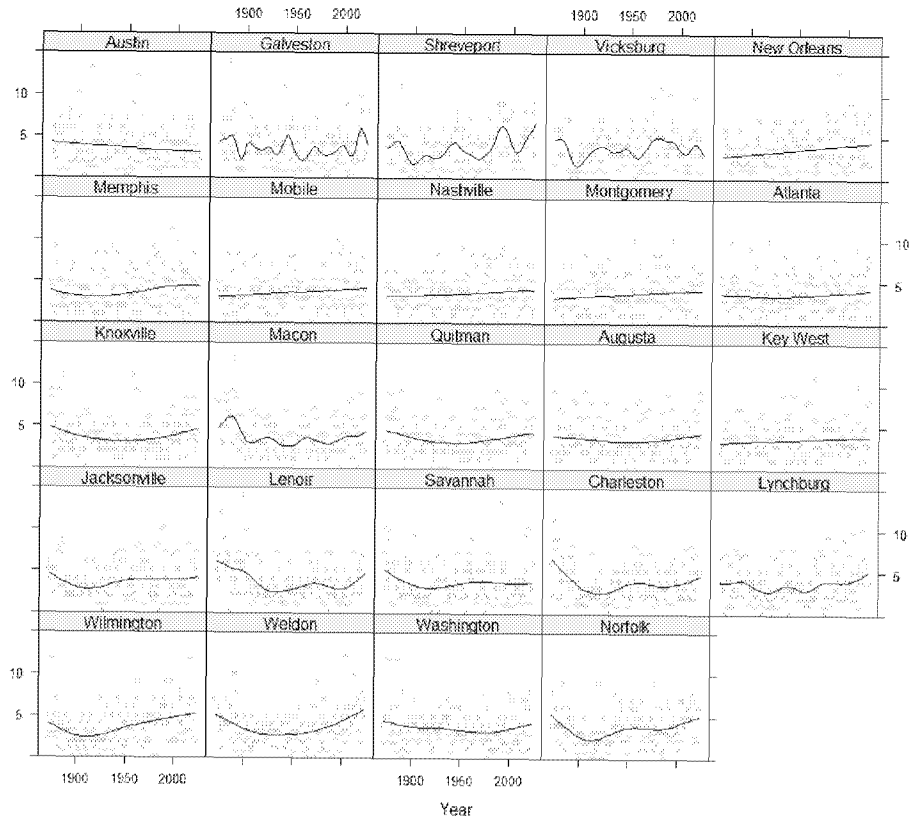
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

Annual No. 99th Percentile Exceedances SE 1873-2024



MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

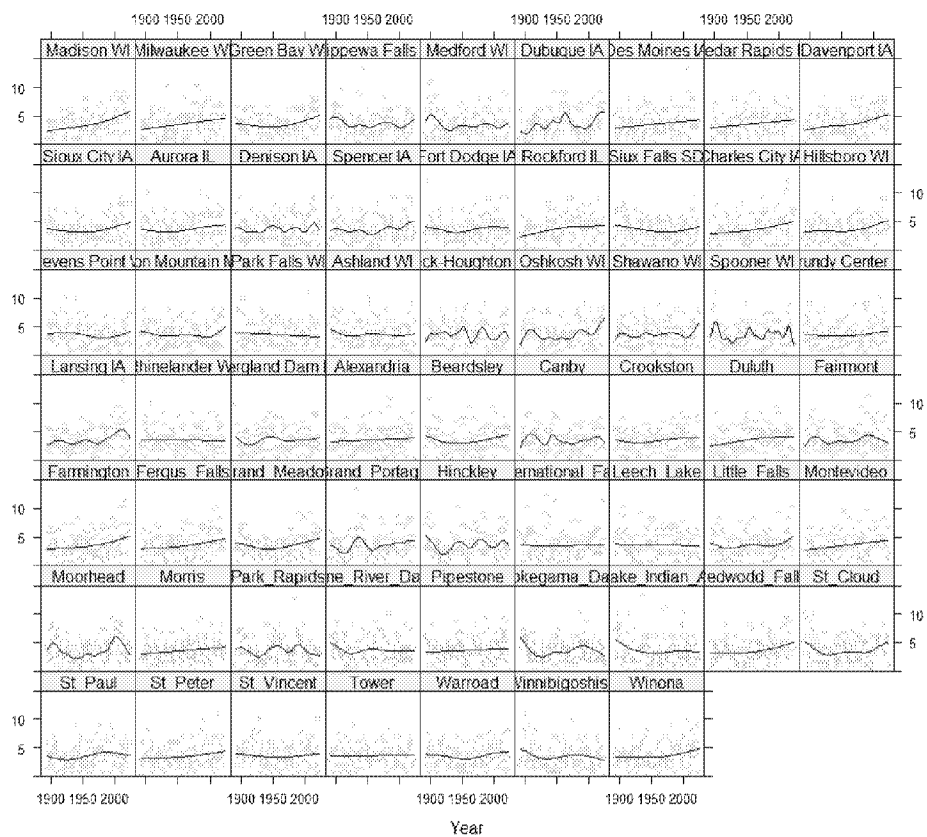
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

Annual No. 99th Percentile Exceedances MW 1893-2024



NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

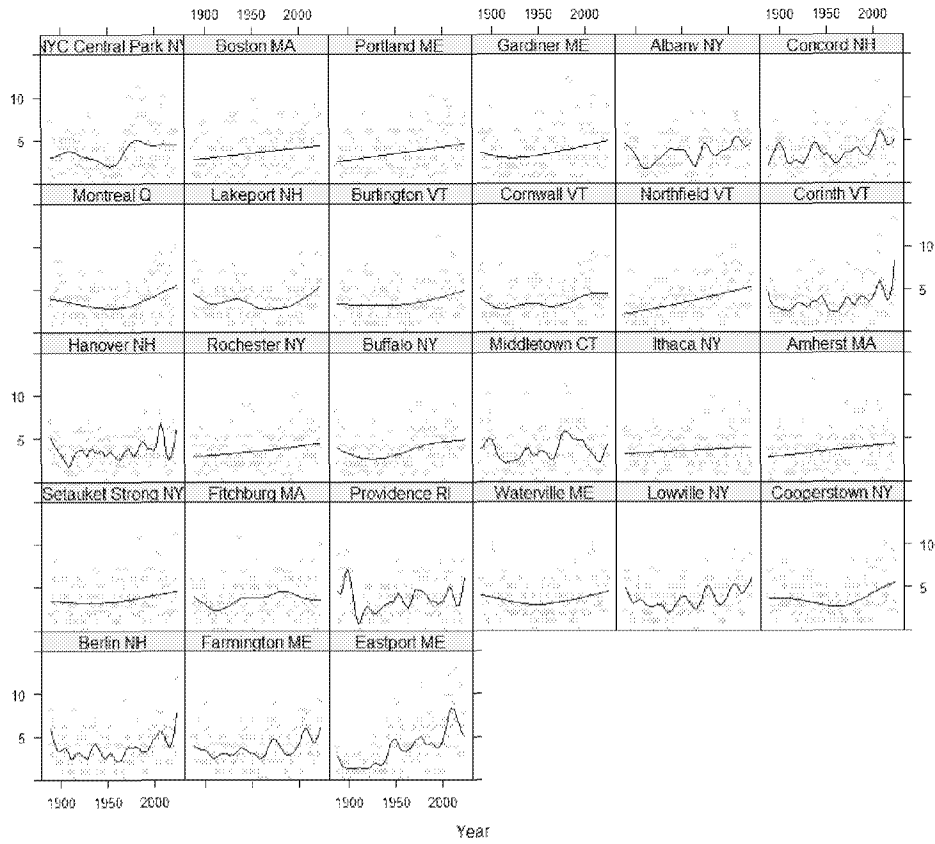
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

Annual No. 99th Percentile Exceedances NE 1888-2024



ABOUT THE AUTHORS

[Insert updated bios]

Critique of the Fifth National Climate Assessment

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EXECUTIVE SUMMARY

This report critically evaluates the Fifth National Climate Assessment (NCA5), finding it an inadequate basis for climate and energy policies. A detailed review of the foundational chapters on climate science raises several key concerns:

Scientific Integrity

- An advocacy tone, particularly in the Overview chapter, that is inconsistent with scientific objectivity
- ~~Advocacy~~ Framing of climate policy as a morality play
- Endemic overconfidence when stating conclusions, including inflated certainty levels and overstatement of findings from underlying sources
- No mentions of dissent, disagreement, controversies, or tradeoffs

Flawed methodology

- Minimal discussion of observational inadequacies
- Use of short time periods for trend analyses; ~~more generally~~ lack of a consistent rule rationale for choosing time scales
- Attribution is implied, not dissected
- Overemphasis on extreme scenarios for future emissions and sea level rise
- Inadequate traceable accounts to support key conclusions

Inadequate Review Process

- A review by the National Academy of Sciences, Engineering, and Medicine (NASEM) failed to challenge ~~identify~~ some fundamental flaws in NCA5
- The NCA5 authors failed to adopt some improvements recommended by NASEM

The report shows NCA5 to be a biased and incomplete picture of climate science that skews toward excessive climate risk. Consequently, NCA5 should not be used as basis for climate and energy policies.

~~Motivated optimism with an advocacy tone~~

~~Subtle advocacy with emphasis~~

~~Attribution is implied, not dissected~~

~~Framing climate as a morality play~~

~~Dissent is invisible~~

~~Minimal discussion of observational limitations~~

~~No mention of tradeoffs~~

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1 INTRODUCTION

1.1 About this Report

This report responds to a request from the Office of Science and Technology Policy (OSTP) Director Michael Kratsios (reproduced in the Appendix-4) MAY HAVE TO MODIFY THIS that we assess the suitability of the Fifth National Climate Assessment (NCA5 2023) for informing climate and energy policies.

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To conduct this assessment, we reviewed NCA5 itself, the National Academies of Science, Engineering and Medicine (NASEM) review of the Third Order NCA5 Draft, and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, the Intergovernmental Panel on Climate Change (IPCC), and other organizations, as writers, reviewers, and study leaders. Further, we have reviewed recent scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted "CWG25").

We find that NCA5 should not be relied on for policy making as it isportrays an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science. Further, we have reviewed recent scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted "CWG25"). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

To support our finding, the following sections of this chapter provide some background on the National Climate Assessments and the standards by which we have assessed NCA5. Chapters 2 through 7 detail important ways in which NCA5 fails to meet those standards. Finally, Chapter 8 summarizes our evaluation of NCA5 and makes recommendations for NCA6.

1.2 About the National Climate Assessments

The [[HYPERLINK "https://www.globalchange.gov/"](https://www.globalchange.gov/)] (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to:

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.
- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was a further expanded effort that was published in two volumes: I Climate Science Special Report (CSSR), and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on “Climate Action” and policy recommendations with a social justice emphasis.

These successive interpretations of the NCA are poorly aligned with the GCRA’s statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then NCA4 misrepresents some important points. Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially deployment of wind and solar power generation.

1.3 Standards for Assessing NCA Products

Beyond the statutory requirements stated above, another pertinent standard is President Trump’s executive order of May 23, 2025, [[HYPERLINK "https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/"](https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/)]. It enumerates some of the characteristics of good science, namely that it should be:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

For an assessment of policy relevant science, it is also important to include statements about the strength of knowledge. The IPCC’s approach to assessing strength of knowledge is based on judgment of the available evidence and agreement among experts. But there are more sophisticated knowledge characterizations for risk management. Here are the elements according to Aven (2017):

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns (issues that are known to matter but are ignored, such as, in this context, natural variability).

2 NCA5 OVERVIEW CHAPTER: ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

NCA5 Chapter 1, "Overview", holds a prominent place in the Report since it summarizes the entire report and is the only section that many will read. Chapter 1 is marred by an activist tone, language that aggressively promotes mitigation policies, and motivated optimism. As such, this chapter adds an imprimatur of scientific authority to naive and simplistic declarations of opinion about public policy. Here are some examples as presented here.

Chapter 1 opens with as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic, that all warming is bad and causes economic damage, and that warming intensifies extreme weather. Such sweeping generalizations go well beyond what science has or can establish. The statement also refers to growing risks without reference to their magnitude – a small risk that grows/increases ~~may~~ might still be a small risk, and a large risk ~~may~~ might be only incrementally worsened.

On the next page the Overview states one finds:

Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits..."

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. Neither the vast body of scholarship on climate science and economics, nor historical experience, support such simplistic claims (CWG25). Not every additional

increment of warming leads to economic harms; in fact, NCA5 Chapter 19 acknowledges that there will also be benefits. Nor is climate policy guaranteed to benefit the economy; it could impose net costs. Such misleading statements are a disservice to policymakers.

Pages 8 and 9 of the Overview promote renewable energy options by noting, correctly, that the leveled costs of wind/solar generation have fallen sharply since 2010, and so offers this rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) significantly increases the total cost of electricity. Further, there are yet unmet synchronization challenges in electrical grids with heavy penetration of wind and solar generation. NCA5 fails to acknowledge these facts. But more importantly, we see no reason for NCA5 to be discussing renewable energy technologies and economics in the context of its mandate.

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Page 17 of the Overview introduces the discussion of risks from extreme weather events by saying "Harmful impacts from more frequent and severe extremes are increasing across the country." This creates the impression that extreme weather events are worsening and that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the exposure and value of assets at risk, it then invokes the NOAA Billion Dollar Dataset as evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG2025 Section 10.2) since it measures the growth of vulnerable infrastructure the economy, not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product. Even though the dataset was still distributed by NOAA at the time of the NCA5, the report authors failed to assess it skeptically and see that it was unfit for the purpose of measuring climate trends.

Page 23 of the Overview states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

~~It is pointless to try to evaluate this statement.~~ This statement can not be evaluated on scholarly grounds, and so. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote alarm, but also the ineffectiveness of the review process in eliminating such statements.

3 OVERCONFIDENCE WHEN STATING CONCLUSIONS

3.1 Inflated certainty levels

Overconfidence in stating conclusions has been an endemic problem in NCA Reports. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

NCA5 uses specific terms to convey information about scientific confidence associated with important findings, observations and projections. The Front Matter of NCA5 states that

confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.

Table 1 from the Front Matter provides calibrated language for confidence assessments:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is obviously inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and by incorrectly applying its own standards. An example is the conclusion about anthropogenic influence on climate change, arguably one of the most important scientific statements of the report.

Key Message 3.1 Traceable Account states:

There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.

while the corresponding statements from IPCC AR5 and AR6 are

AR5: It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together. (IPCC, 2013)

AR6: The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by –0.1°C to +0.1°C, and internal variability changed it by –0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, AR5 refers to “*more than half* of the observed warming” and AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

3.2 Overstating findings in underlying sources

Although we did not do a detailed audit of NCA5’s use of source material, spot checks suggest a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in some areas and attributes it to “climate change”:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

NCA5 attributes the claim to Knutson and Zeng (2018). But Knutson and Zeng did not say these things nor did they analyze this particular period. For 1981-2010 they cautioned that observed changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States.

As another example of overstating findings, NCA5’s Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is apparently attributed to Diffenbaugh *et al.* (2018) and Kirchmeier-Young and Zhang (2020). Diffenbaugh *et al.* presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S., extreme rainfall events are currently more frequent than in simulations, and the ratio of occurrences will rise under future warming simulations. This is not “robust” evidence of anthropogenic influence since it requires readers to assume that climate models accurately simulate regional precipitation patterns, something that the IPCC AR6 states is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang used three global climate models to analyze extreme 1- and 5-day events in North America. They noted large differences among the three models in their simulated precipitation changes, and two of the three models failed to yield attribution for 5-day events for the North America mean. [DON’T UNDERSTAND THIS PHRASE] THIS IS AN ATTEMPT TO MAKE SENSE TO ME IF WORDED AS “for the North American mean of 5-day events.” In other words, the models disagreed on whether the observed changes were anthropogenic. Both of the cited references utilized the implausible RCP8.5 scenario (Chapter 6 of this Report) and began their “historical” observational records only in 1961. Here again this is not “robust” evidence, it is merely suggestive, particularly since other studies have found natural variability to be predominant.

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3.3 Example: Emergent constraints

Some of the overconfidence expressed by NCA5 arises by omitting discussion of counterevidence in the peer reviewed literature, ignoring dissent and disagreement. An example is the topic of "emergent constraints". NCA5 Chapter 3 page 17 invokes this concept to support its claim that key uncertainties in climate model projections have been reduced:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as "emergent constraints." The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie climate model behavior to climate observations in hopes of generating insight into real-world equilibrium climate sensitivity to a doubling of carbon dioxide (ECS). Climate models exhibit a wide range of ECS values. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes, but in high-ECS models the correlation is weak. Then researchers could examine whether the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a proliferation of proposed correlations with little physical motivation. NCA5 alludes to this in the Traceable Accounts section (p. 3-40) but not in the main Chapter text. As shown by Schlund *et al.* (2020), many emergent constraints patterned on CMIP5 models (Coupled Model Intercomparison Project Phase 5, used for the IPCC 5th Assessment Report) failed to work on CMIP6 models (used for the IPCC 6th Assessment Report). In other words, the observed correlations in CMIP5 models between ECS and cloud processes present in CMIP5 models failed to show up were absent in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the climate system. As a result, emergent constraints estimated on CMIP5 models increased the uncertainty of ECS, rather than decreasing it as intended and as claimed by NCA5.

Yet NCA5 described the use of emergent constraint analysis as an advance that reduced the uncertainty of ECS and climate model projections (p. 3-38):

Emergent constraints have been widely applied to reduce the simulated spread in the climate feedbacks that shape climate sensitivity.

4 ARBITRARY AND AMBIGUOUS TREND ANALYSES

CWG25 Chapter 6 discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We provided examples from analysis of river flooding, heatwaves, and extreme precipitation to show how assertions about apparent trends based on short data sets fall apart when looking at considering longer versions of the same data sets. NCA5 uses varying time periods for trend analyses, especially in Chapter 2 (which is focused on trends), without explaining why shorter or longer intervals were chosen. For example, page 2-4 defines temperature trends with respect to over the interval since the late 1800s whereas page 3-29 presents temperature trends over 1972-2021. Page 2-11 compares rainfall over the 2002-21 versus 1901-1960 intervals, while page 2-18 uses the interval since the late 1950s to compute trends.

A further problem is that NCA5 uses the term “trend” repeatedly without indicating if it is statistically significant (i.e., distinguishable from random variability); the ambiguity creates the impression all the observed changes were significant, but readers are left to speculate. All climate variables will, in principle, drift up or down over any particular time interval. Identifying the change as a trend requires showing that it is statistically significant using a variance estimator suitable for the type of data being analysed. Of particular importance is choosing a method robust to the serial correlation which that is frequently present in climate data. Throughout Chapters 1 to 3, references are made to “trends” without explaining how they were computed. The exception was on page 1-19 which refers to urban temperature trends being calculated using the Theil-Sen estimator, although that method does not seem to have been used elsewhere. The one case where reference is made to statistical significance was on Page 2-9, referring to a trend in Atmospheric Optical Depth, but there is no explanation is given of how significance was determined. Page 2-19 refers to regional trends in droughts being “robust” but again fails to explain how the term was defined.

~~In this chapter when we refer to calculation of trends in precipitation, we use ordinary least squares to compute the linear trend over the entire sample length and we use the Vogelsang and Franses (2007) variance estimator which is robust to general forms of serial correlation. [IS THIS PARAGRAPH A QUOTE FROM NCA5? IF SO, NEED TO INDENT AND ADD SOME COMMENTARY. IF NOT, IT ISN'T CONNECTED TO THE REST OF THE TEXT]~~

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4.1 Average and Extreme Precipitation

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4.1.1

In CWG25 Section 6.4 we presented analyses of updated data for the same locations [SAME AS WHAT?] (and many others), in all cases finding both considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences. ~~In this chapter section, when we refer to calculation of trends in precipitation, we use ordinary least squares to compute the linear trend over the entire sample length and we use the Vogelsang and Franses (2007) variance estimator which is robust to general forms of serial correlation. [IS THIS PARAGRAPH A QUOTE FROM NCA5? IF SO, NEED TO INDENT AND ADD SOME COMMENTARY. IF NOT, IT ISN'T CONNECTED TO THE REST OF THE TEXT]~~

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NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion. ~~Instead~~ Instead, it refers to changes “since the 1950s”; NCA5 Figure 2.8 suggests 1958 might be the intended start date. Under Key Message 2.2, “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16), NCA5 states (p. 2-18):

Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

In addition to our concerns that inferences about trends are contingent on choice of time scale, if the intended meaning of this statement is that positive and significant trends are found in heavy precipitation events across CONUS, we cannot reproduce it. Details of our analysis can be found at [LINK TO BRIEF WRITEUP ON THIS](#) can we just reference CWG [HERE](#)

Based upon our analysis, the following is a more accurate summary of what U.S. precipitation data show.

There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This argues against attribution of changes in precipitation to anthropogenic warming.

4.2 Heatwaves

In contrast to NCA5, NCA4 examined heat extremes across the entire 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies. NCA4 stated:

[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s.

(NCA4 pp. 190-191)

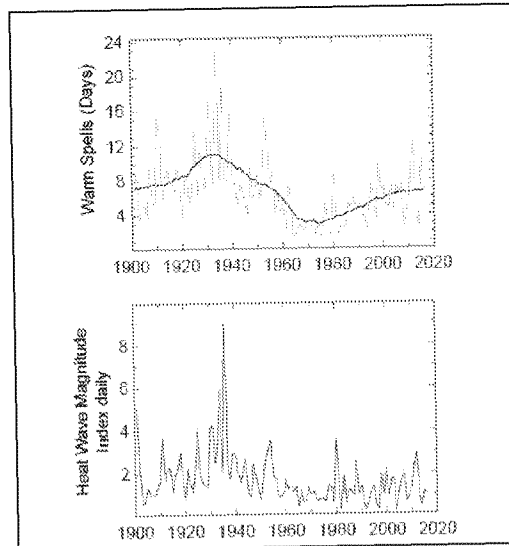


FIGURE 3. U.S. Heatwaves since 1900. Reproduction of NCA4 Figure 6.4

Contrast this careful and factual language from NCA4 with NCA5 Key Message 2.2: “Extreme Events Are Becoming More Frequent and Severe.” This blanket statement is followed by NCA5 Figure 2.7 (reproduced as Figure 4 below) which shows the number of hot days, cold days and warm nights (respectively in panels a—c) over the period 2002-2021 compared to 1901-1960. [Presumably these are annual counts, although not stated in the caption.]

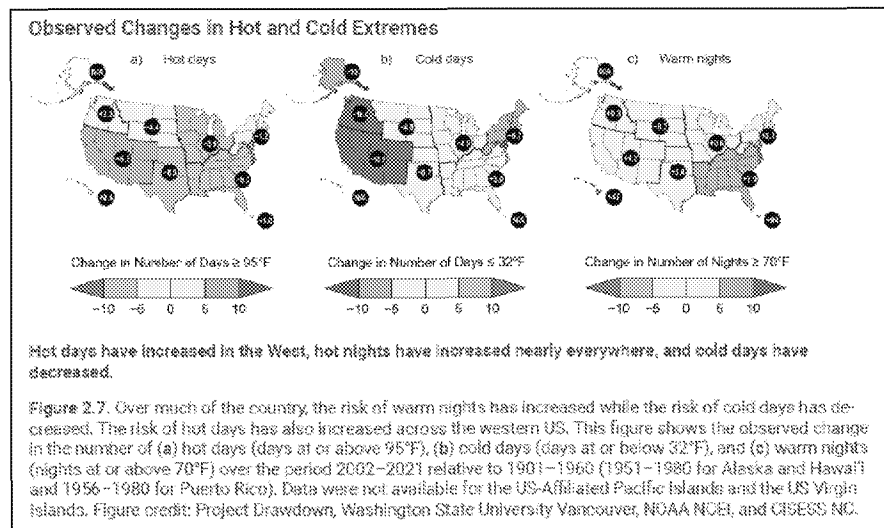


FIGURE 4: Reproduction of NCA5 Figure 2.7.

Close inspection shows that this figure actually contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of NCA4. Notwithstanding Key Message 2.2, the leftmost panel in NCA5 Figure 2.7 above shows that over most of CONUS the number of extreme heat days has *decreased* in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted as it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 Chapter 2 elaborates on Key Message 2.2 by stating (page 2-16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But while it mentions the increase in hot days in the West, it fails to mention the decrease everywhere east of the Rockies. On the next page (page 2-17) it raises the comparison to the 1930s and then switches to discussing global counts:

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

The reference to a global trend seems to be an attempt to tie heatwaves to anthropogenic climate change. But the obvious question, unaddressed by NCA5, is why one region follows the global pattern of increasing heatwaves while most of the country is trending in the opposite direction. These issues are addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures are driven more by natural variability than by the small anthropogenic forcing. The analysis in CWG25 shows that for both (a) hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is no hotter than a century ago in the U.S. Thus, the NCA5 claim that “multiday

heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal and spatial domains to encompass all available data (Chapter 6 and Figure 6.3.6 of CWG25).

NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG25 Section 8.6.1 discussed this event in detail, reviewing the multiple peer reviewed studies that explained the unusual meteorological context was unrelated to human-caused climate change, a point omitted from the NCA5 discussion.

NCA5 finally addresses the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator ([[HYPERLINK "https://www.globalchange.gov/indicators/heat-waves"](https://www.globalchange.gov/indicators/heat-waves)]) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed this part of NCA5 in CWG25 Section 6.3. The figure referenced by NCA5 uses a short time period which begins in the 1960s, the coldest decade in the last 100 years, thus suppressing any comparison to the 1930s. Further, nighttime temperatures in urban areas have increased faster than daytime temperatures (which NCA5 acknowledges), but this is a signature of urban heat islands and not a good metric of climate change. CWG25 found that the occurrence of hot days ($\geq 95^{\circ}\text{F}$) has recently increased in the West, but declined since 1899 in the remainder of the country, and in the nationwide average, since 1899.

5 INADEQUATE TRACEABLE ACCOUNTS

NCA3 began the practice of including a section on Traceable Accounts at the end of each chapter. This is the description from NCA5:

Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team’s expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.

The Traceable Accounts for each Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps

- Description of Confidence and Likelihood

The Traceable Accounts could have addressed the statutory requirement that the NCA discuss scientific uncertainties. They could also help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5's Chapters 2 and 3 are uneven, often superficial and uninformative.

An example of a deficient Traceable Account is NCA5's Key Message 2.2: "Extreme Events are Becoming More Frequent and Severe". The "Description of the Evidence Base" offers two paragraphs, the first summarizing the findings and the second generically describing the types of data that can be used for storms. "Major Uncertainties and Research Gaps" focuses on the uneven distribution across U.S. populations due to differences in exposure and vulnerability. The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data apart from reanalysis products.

But the most astonishing deficiency is in the "Description of Confidence and Likelihood." One of the statements in Key Message 2.2 is:

Hurricanes have been intensifying more rapidly since the 1980s (*high confidence*) and causing heavier rainfall and higher storm surges (*high confidence*).

The Description of Confidence and Likelihood includes the following statement:

Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.

No reference to journal publications or a specific data set is made anywhere in the chapter regarding hurricane-induced precipitation or storm surge to support this *high confidence* conclusion.

The Traceable Accounts for the various Key Findings of Chapter 3 have some substantial inconsistencies. Consider

Key Message 3-1: Human activities have caused global warming.
Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

The Uncertainties section addresses only uncertainties in radiative forcing by greenhouse gases, ignoring the great uncertainty in model responses ~~to that forcing~~ (CWG25 Chapters 4 and 5). In contrast, the Traceability Analysis of Key Message 3-4 ("Humans Are Changing Earth System Processes") raises the problem that relatively little is known about the role of natural variability at the regional scale. From its Description of Evidence Base:

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In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals.

And from its Major Uncertainties and Research Gaps:

For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.

These statements are among the most scientifically credible in the entire NCA5 and they directly undercut the confidence assigned to Key Message 3-1.

There is also a generic problem in tracing NCA5's Traceable Accounts. The Front Matter of NCA5 states:

Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.

Clicking on the 'eyeball' icon does not reveal the metadata information; instead a "Contact Us" email appears, addressed to the USGCRP. This is an inadequate way to archive the metadata information.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives of the NCA.

6 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to "project major trends for the subsequent 25 to 100 years," NCA5 relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

CWG25 Section 3.2.1 presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. IPCC AR6 published in 2021 stated that "The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments," and that same year UN Climate Negotiators (COP) stopped using scenarios above 4.5.

NCA5 makes the following observations about the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that

the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue, NCA5 otherwise ignored the problem. A keyword search of NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, nine NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios.

The problem of relying on extreme scenarios is particularly acute for NCA5’s sea level rise projections. The sea level rise scenarios used in NCA5 do not relate directly to the SSP emissions scenarios, but rather to specified amounts of sea level rise by 2100. Table 4 of NCA5’s “Guide to Using this Report” reproduced below shows that Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5						
Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2022.”						
Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

TABLE 1: Reproduction of Table 4 from the Front Matter of NCA5

Considering only projections representing processes quantified with at least medium confidence, IPCC AR6 assessed global mean sea level projections for all emissions scenarios (including implausible extreme emissions scenarios) for 2100 to fall between 0.2 and 1.6 m (5th–95th percentile range). Nevertheless, the range of sea level rise scenarios considered by NCA5 extends to 2.0 m. Further, NCA5 fails to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which also corresponds to the average rate of sea level rise over the past century.

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Chapter 9 of NCA5 offers the following predictions of sea level rise:

“Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2).”

The projected sea level rise values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the [[HYPERLINK "https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level"](https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level)] global sea level rise from 2000-2024, which is only approximately 3.4 inches (0.28 feet). NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000-2024, an exceedingly implausible outcome. Chapter 9 further states:

“Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9-13 inches.”

...
“There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050”

In summary, NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios or to plausible global warming levels. The NCA5 scenarios include two that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes in which there is low confidence. Projections to 2050 require rates of sea level rise from 2025 to 2050 that are more than triple the rate observed during 2000-2024. Further, NCA5 ascribes *high confidence* to these sea level rise projections. CWG25 Section 7.3 provides further context for USGCRP projections of extraordinary sea level rise in the next 25 years.

More generally, NCA5’s inclusion of, and even focus on, implausible extreme scenarios supports creates projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

7 CONFLATION OF NATURAL AND ANTHROPOGENIC CLIMATE CHANGES

NCA5’s Glossary defines “climate change” as a change in climate for any reason. This is technically correct, but at variance with the (now) popular perception of all climate changes being anthropogenic. The distinction is not academic- it is central both to attribution questions and to projections, since anthropogenic changes would respond to mitigation, while natural changes are unavoidable.

The discussion on NCA5 page 2-4 begins “Human activities are changing the climate”, then goes on to list evidence for anthropogenic GHG emissions and climate warming. The next paragraph begins “Climate change is happening now in the United States. Including Alaska, the continental US has been warming about 60% faster than the planet as a whole since 1970.” The implication is that the warming of CONUS faster than the planetary average is an effect of GHG emissions. But it is an artifact of the Earth’s surface being 70 percent ocean. Since the ocean warms more slowly than land, comparison of any land surface outside the tropics with the global average would show the land surface to be warming faster than the global average, regardless of the cause of the warming.

The same page goes on to say “Climate change is already affecting people in the United States. Extreme heat was estimated to be responsible for more than 700 deaths per year between 2004 and 2018 although some estimates put heat-related mortality closer to 1,300 deaths annually.” But extreme heat, whether natural or not, has always been a risk to human health. As to trends, the data show that adaptation has caused the mortality burden of extreme heat to drop substantially in recent decades (CWG25 Section 10.3.1).

Consider also the NCA5 statement on precipitation ~~that we~~ cited in Section 3.2:

Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

The attribution is superfluous because the statement is a tautology by NCA5's definition of climate change. But its gratuitous inclusion effectively attributes the observed trend to greenhouse gas emissions.

Exploitation of the ambiguity ~~inherent in the term~~ "climate change" is endemic to NCA5. The NASEM review (pp. 23-24) commented on this problem as follows:

The draft NCA5 report frequently describes "change" but does not consistently distinguish between natural variability and climate change. This lack of clarity can be misleading for the reader by creating the misconception that some impacts that are the result of the combination of natural variability and climate change are instead solely due to climate change... it is important for NCA5 authors to accurately identify the multiple drivers of change (including global change), in addition to climate change, and accurately attribute impacts. Clearly describing impacts due to natural variability, climate change, or a combination of the two is important not only for informing policy decisions, but also for building public understand ~~[sic]~~ and trust in the report's messages. Climate change and natural variability should be clearly defined in the glossary and natural variability could be introduced in chapter introductions when the concept is important for understanding key messages.

This could have been easily addressed, ~~for example,~~ by reserving the term "climate change" for anthropogenic changes and using "climate variability" for natural changes. But the NCA5 authors seemingly ignored their recommendation.

A separate but related issue is use of the term "climate change" to refer to increases in socioeconomic vulnerabilities that have anthropogenic ~~causes unrelated to but non-GHG-related causes~~. NCA5 page 1-19 states "Climate change exacerbates inequalities." But the issue discussed is the negative correlation between neighborhood-level income and land surface temperatures (~~LST~~) in urban areas. To the extent the correlation is real, the most likely explanation is that low-income households concentrate where housing is less expensive, which ~~may might~~ be in neighborhoods with less nearby parkland and tree cover; ~~that, which~~ has nothing to do with CO₂ emissions.

8 SUMMARY EVALUATION OF NCA5 AND RECOMMENDATIONS FOR NCA6

This chapter summarizes our evaluation of NCA5 relative to OSTP's charge: whether NCA5 (1) complied with the USGCRP's statutory obligation; (2) adheres to the core tenets of Gold Standard Science; and (3) can suitably inform federal climate and energy policy. The points made in this summary analysis refer to specific sections of this report as well as to the CWG25 report.

8.1 Compliance with USGCRP's statutory obligation

As cited in Section 1.2 of this report, the Global Change Research Act requires an assessment that:

- (1) integrates, evaluates, and interprets the findings of the [Global Change Research] Program and discusses the scientific uncertainties associated with such findings;
- (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and
- (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

We deem NCA5 to have fallen short when evaluated against these criteria because of the following major shortcomings (each is detailed in the sections and chapters cited):

- Inadequate assessment of the relevant topics in climate science and the hazard components of climate impacts (such as hurricanes and floods). NCA5 instead focuses on evaluation of societal vulnerabilities (such as flood infrastructure, access to air conditioning, etc.), “Climate Action,” and policy recommendations with a social justice emphasis (Section 1.2).
- Overconfidence in conclusions and inadequate assessment of uncertainties (Section 3.1.5)
- Inadequate discrimination between natural and human-induced causes of trends and impacts (Chapter 7)
- Inadequate analysis of climate trends by relying on short time periods (Chapter 6)
- Uncritical evaluation of emission scenarios and climate model simulations in making projections for the next 25 to 100 years (Chapter 6; Section 3.2.1 and Chapter 5 of CWG25).

8.2 Adherence to the tenets of Gold Standard Science

With respect to the tenets of Gold Standard science listed in Section 1.2 of this report, we have identified the following major shortcomings in NCA5:

- **Lack of reproducibility.** In the few examples that we examined closely, we identified an instance where we could not reproduce the findings of the NCA5, a task that should require only rudimentary data analysis (Section 4.1)
- **Lack of transparency.** In many instances, the Traceable Account fails to justify the Key Finding. Metadata was not readily accessible. (Chapter 5)
- **Inadequate communication of error and uncertainty.** The Traceable Account for each Key Message provides a section on Major Uncertainties and Research Gaps; most of the accounts that we examined were superficial and uninformative. (Chapter 5)
- **Not skeptical of findings and assumptions.** The main text of the chapters is, with few exceptions, not skeptical of its findings and assumptions and does not mention dissent or disagreement. (Chapters 3 and, 5)
- **Some hypotheses and Key Messages are not falsifiable.** Key Message 13.4 is but one of many examples: “Equitable Distribution of Transportation Trade-offs and Benefits Requires Community Involvement.”
- **Failure to acknowledge benefits** of warming and additional atmospheric CO₂ (CWG25 Section 2.1, Chapter 9)
- **Inadequacy of the peer review process.** The review of the NCA5 Third Order Draft by National Academies of Science, Engineering and Medicine (NASEM) identified some of the deficiencies we have noted, but the NCA5 authors were not obligated to adopt the NASEM recommendations. More importantly, we’ve identified many other deficiencies in NCA5; the NASEM review did not point them out and thus lacked the rigor expected of NASEM reports.

8.3 Suitability for informing Federal climate and energy policy

We assess that the selection and presentation of information in NCA5 makes it an unreliable basis for U.S. climate and energy policy making. For each of the elements of knowledge characterization suitable for risk management listed in Section 1.3, here are specific examples where NCA5 falls short

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
 - NCA5 focused on implausibly extreme scenarios for emissions and sea level rise scenarios and made policy recommendations without adequate consideration of the costs
- The degree to which data/information exists and are reliable and relevant
 - NCA5's unjustified assumptions about model reliability, and its use of short time periods for analysis, does not support its high-confidence conclusions
- The degree to which there is disagreement among experts, including those from different environments or academic fields
 - While NCA5 was an interdisciplinary effort, the concerns we have raised all point to a failure to canvass or communicate the full range of evidence, including data and research findings that speak against Key Messages.
- The degree to which the phenomena involved are understood and accurate models exist
 - NCA5 is not appropriately skeptical of the ability of climate models to attribute the causes of warming and extreme events or to project future climates, especially at the regional level
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns
 - A major NCA5 shortcoming is its dismissal of natural climate variability in many contexts where it should have been a major consideration

NCA5 is also problematic for informing policy because its ~~hyperbolic exaggerated~~ language promotes alarm and advocates for specific policies without a proper risk analysis. The NASEM Review of the NCA5 underscores the endemic nature of this problem - their review appears to be written by authors who share many of the biases of the NCA5 team, with an inordinate focus on social and policy issues. ~~It is then not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. Further, the field of climate science has been politicized by NetZero mandates. This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.~~

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Philip Handler, President of the National Academy of Sciences, identified the problem ~~forty-five years ago in an~~ [HYPERLINK "<https://science.sciencemag.org/content/208/4448/1093>"] ~~that still resonates.~~

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~~Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.~~

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~~NCA4 provided was a better policy-informing assessment than NCA5. It offered a -in terms of a more thorough consideration climate science, consistently used of data back to 1901, and had less of an advocacy tone. Apart from the issue of the But NCA4 is almost a decade out of date. More importantly, it NCA4 being outdated for reliance in 2025, NCA4 shared shares the following NCA5's endemic problems of overconfident conclusions, inadequate treatment of natural variability, inadequate traceable accounts and communication of uncertainty, and over reliance on extreme scenarios, with NCA5~~

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- ▲ ~~Over confidence in conclusions~~
- ~~Inadequate treatment of natural variability~~
- ~~Inadequate Traceable Accounts and communication of uncertainty~~
- ~~Over reliance on extreme scenarios~~

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8.4 Recommendations for NCA6

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While we have assessed NCA5 to be scientifically inadequate and unsuitable as a basis for decision-making, one can imagine a different National Climate Assessment that meets statutory and policy maker requirements. The goal should be not to persuade, but to impart understanding by being objective, transparent and complete. A suitable NCA would be an important complement to IPCC assessments to the extent that its analysis and conclusions differ from the "consensus" of the IPCC reports and additional topics are addressed. Such a report would promote a more open scientific discussion and a more informed policy debate.

We recommend that the NCA6 have a narrower scope than NCA5, refocusing on climate science, including natural climate variability, with topics to include:

- How the climate has changed in the past. The U.S. has the best and longest meteorological records and they should be examined and displayed in their entirety. Trend analyses should include longest periods available and employ suitable statistical methods. Local paleoclimate data should be considered where available. Analysis should demonstrate not only how the climate has varied and changed, but also regional heterogeneity. Standard, easily understandable metrics should be employed.
- The range of climatic and weather conditions, including extremes, that have occurred in the past and can reasonably be expected to occur in U.S. regions over the near future. ~~A salient example of an salient acute failure is the NCA5 Chapter 26, (region that includes Texas) that which fails to mention the historical occurrence and future risk of flash floods in the Texas Hill Country. The regional chapter for REGION that includes Texas only stated that SOMETHING MISSING HERE?? IPCC MAYBE MENTION WHAT WAS SAID ABOUT THE GOOD REGIONAL CHAPTER THEN INCLUDE LINK TO YOUR FINAL ANALYSIS~~
- A critical survey of current global and regional modeling capabilities and their suitability for regional impact assessments and projections. This would include an assessment of their ability to reproduce observed changes. It should also discuss alternative methods for generating ~~projections and forecasts scenario projections~~ on regional and decadal scales, along the lines of Chapter 10 of the IPCC AR6 WGI Report.
- Assessment of the impacts of recent historical climate variability and change on ecosystems and society. Where long-term data indicate a detectable regional change, regional projections can be made for the period 2030-2050. Emissions scenarios exceeding RCP4.5/SSP2-4.5 and

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ECS values exceeding 4°C should not be used. Regional projections to 2100 have no credibility at this time, and so should not be included in NCA6.

It is important that climate projections be assessed in context of current science capabilities. The pressures toward spatially or temporally precise projections should be resisted as the current models are nowhere up to the task (an example is discussed in CWG25 Section 5.8). In that light, the many pages of NCA5 devoted to projected regional and sectoral impacts have little value.

Given the substantial deficiencies and bias in NCA5 that we have identified, producing an objective NCA6 report with the current NCA organizational construct would be a challenge. A NASEM review could help, but only if the selected participants reflect full viewpoint diversity and do not simply mirror the assumptions and biases of past NCA teams. We regard the CWG25 report to be a good start on NCA6 in terms of scope and objectivity, including adherence to the tenets of Gold Standard Science.

More broadly, we recommend a rewrite of the Global Change Research Act. The current mandate is vague and off point, allowing successive NCA teams to interpret the mandate as they see fit. Moreover, it is becoming increasingly clear that current and foreseeable models are not fit-for-purpose to describe regional climates, let alone usefully project them for 25 to 100 years. Further, the use of the term “global change” is ambiguous and outdated.

9 REFERENCES

- Aven, Terje (2017) “Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices,” *Reliability Engineering & System Safety* 167 (November 2017): 42–48 [HYPERLINK "<https://www.sciencedirect.com/science/article/pii/S0951832016306950>"]
- Climate Working Group (2025) Impacts of Carbon Dioxide Emissions on the U.S. Climate. Washington DC: Department of Energy, May 27, 2025.
- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. <https://doi.org/10.1126/sciadv.aao3354>
- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308–13313. <https://doi.org/10.1073/pnas.1921628117>
- Knutson, Thomas and Fanrong Zeng (2018) “Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends” *Journal of Climate* 31(12) [HYPERLINK "<https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml>"]
- National Academies of Sciences, Engineering, and Medicine. 2023. *Review of the Draft Fifth National Climate Assessment*. Washington, DC: The National Academies Press. [HYPERLINK "<https://doi.org/10.17226/26757>"].
- NCA4. (2017). *Climate science special report: Fourth National Climate Assessment, Volume I* (D. J. Wuebbles, D. W. Fahey, and K. A. Hibbard, Eds.). U.S. Global Change Research Program. [HYPERLINK "<https://doi.org/10.7930/J0J964J6>"]
- NCA5. (2023). *Fifth National Climate Assessment* (A. R. Crimmins et al., Eds.). U.S. Global Change Research Program. [HYPERLINK "<https://doi.org/10.7930/NCA5.2023.CH1>"]
- Schlund, Manuel, Axel Lauer, Pierre Gentine, Steven C. Sherwood, and Veronika Eyring (2020) Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6?

Earth System Dynamics 11 1233-1258 [[HYPERLINK "https://doi.org/10.5194/esd-11-1233-2020"](https://doi.org/10.5194/esd-11-1233-2020)]

APPENDICES

10 APPENDIX: 1: CHARGE TO THE REVIEW

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ABOUT THE AUTHORS

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Review of the Fifth National Climate Assessment

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EXECUTIVE SUMMARY

This report critically evaluates the Fifth National Climate Assessment (NCA5), finding it an inadequate basis for climate and energy policies. A detailed review of the foundational chapters on climate science raises several key concerns:

Scientific Integrity

- An advocacy tone, particularly in the Overview chapter, inconsistent with scientific objectivity
- An endemic overconfidence when stating conclusions, including inflated certainty levels and overstatement of findings from underlying sources

Flawed methodology

- Use of *ad hoc* time scales for trend analyses in areas such as precipitation and heatwaves
- An overemphasis on extreme scenarios for future emissions
- Inadequate traceable accounts to support key conclusions

Deficient Review Process

- A review by the National Academy of Sciences, Engineering, and Medicine (NASEM) failed to challenge some fundamental flaws in NCA5
- The NCA5 authors failed to adopt some improvements recommended by NASEM

The report shows NCA5 to be a biased and incomplete picture of climate science that skews toward excessive climate risk. Consequently, NCA5 should not be used as basis for climate and energy policies.

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1 INTRODUCTION

1.1 About this Report

This report responds to a request from OSTP Director Michael Kratsios (reproduced in Appendix 1) that we assess the suitability of the Fifth National Climate Assessment (NCA5 2023) for informing climate and energy policies.

To conduct this assessment we reviewed NCA5 itself, the National Academies of Science, Engineering and Medicine (NASEM) review of the Third Order Draft, and the USGCRP responses to that review. We have drawn upon our long experience working on advisory reports, including for the NASEM, the IPCC-Intergovernmental Panel on Climate Change (IPCC) and other organizations, as writers, reviewers and study leaders.

We find that NCA5 should not be relied on for policy making as it is an incomplete and misleading picture of our understanding of the changing climate and the risks it poses to the nation. NCA5 was selective and incomplete in its survey of climate science as of its publication in 2023 and has become even more so in the years since. We have reviewed many key scientific developments in a separate report to Energy Secretary Wright (Climate Working Group 2025, herein denoted "CWG25"). The overall effect of the biases and omissions of NCA5 is an excessively dire picture of climate risk.

To support our finding, the following sections of this chapter provide some background on the National Climate Assessments and the standards by which we have assessed NCA5. Chapters 2 through 6 detail important ways in which NCA5 fails to meet those standards. Chapter 7 then follows with an assessment of the NASEM review. Finally, Chapter 8 summarizes our evaluation of NCA5.

1.2 About the National Climate Assessments

The [HYPERLINK "https://www.globalchange.gov/"] (USGCRP) was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to develop and coordinate "a comprehensive and integrated United States research program which will assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."

The National Climate Assessment (NCA) Reports evolved from the GCRA requirement to

Prepare and submit to the President and the Congress an assessment which (1) integrates, evaluates, and interprets the findings of the Program and discusses the scientific uncertainties associated with such findings; (2) analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity; and (3) analyzes current trends in global change, both human-induced and natural, and projects major trends for the subsequent 25 to 100 years.

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The five NCA Reports to date have interpreted this mandate in different ways:

- NCA1 (2000) was a multidisciplinary effort to study and portray in regional detail the potential effects of human-induced global warming on the United States.
- NCA2 (2009) was a relatively short report that not only focused on the potential consequences of climate change but also sought to identify potential adaptation measures and identify the highest priorities for future research.

- NCA3 (2014) was an expanded effort that continued along the lines of NCA2, and was distinguished by a comprehensive review process, including a review by the National Academy of Sciences. NCA3 introduced a traceability analysis for each key finding, including a description of uncertainties.
- NCA4 (2017/2018) was a further expanded effort published in two volumes: I Climate Science Special Report, and II Impacts, Risk, and Adaptation in the United States. This was the first NCA report to devote significant effort to assessing climate science.
- NCA5 (2023) returned to a single volume format, reducing discussion of climate science to a cursory two chapters, with continuing with a focus on regional and sectoral impacts of climate change. NCA5 expanded its remit to topics that are arguably outside the purview of the USGCRP, focusing on "Climate Action" and policy recommendations with a social justice emphasis. NCA5's self-description is reproduced as Appendix II.

These successive interpretations of the NCA are poorly aligned with the GCRA's statutory requirements. Only NCA4 gives serious consideration to climate science, which receives the great majority of USGCRP funding, and even then misrepresents some important points (Section 1.4 below offers an example). Natural climate variability is essentially dismissed as unimportant in NCA4 and barely mentioned in NCA5 in most contexts, despite the mandate to include both human-caused and natural climate change. Most significantly, NCA5 has redirected the focus away from climate science and even the hazard elements of impacts, towards evaluation of societal vulnerabilities and advocacy for particular policy options, especially wind and solar power. The cover image for the NCA5 Report is the installation of a solar panel.

1.3 Standards for Assessing NCA Products

~~In Appendix 2 we include a letter of guidance from the Office of General Counsel, U.S. Department of Energy, summarizing the statutory requirements governing USGCRP work products in general and NCA products in particular.~~

~~We can summarize the standards applicable to the NCA as follows:
—details—~~

Beyond the statutory requirements stated above, we draw attention to two other pertinent standards. President Trump's executive order of May 23, 2025, "[[HYPERLINK "https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/"](https://www.whitehouse.gov/presidential-actions/2025/05/restoring-gold-standard-science/)]" enumerates some of the characteristics of good science:

- i. reproducible;
- ii. transparent;
- iii. communicative of error and uncertainty;
- iv. collaborative and interdisciplinary;
- v. skeptical of its findings and assumptions;
- vi. structured for falsifiability of hypotheses;
- vii. subject to unbiased peer review;
- viii. accepting of negative results as positive outcomes; and
- ix. without conflicts of interest.

Although these should be self-evident to those trained in science, it is surprising that some scientists have found them controversial (Dellawalla et al. 2025).

There are other desiderata for scientific reports that will be highly influential on climate policymaking. Among them are statements about the strength of climate knowledge. The IPCC's approach is based on judgment of the available evidence and agreement among experts. More sophisticated knowledge characterizations for risk management include (Arven 2017):

- The degree to which the assumptions made are reasonable/realistic based on background knowledge
- The degree to which data/information exists and are reliable and relevant
- The degree to which there is disagreement among experts (including those from different environments or academic fields)
- The degree to which the phenomena involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined with respect to unknown knowns

Good climate and energy policies balance the risks and benefits of a changing climate against the world's growing demand for reliable and affordable energy. To strike that balance, policymakers must understand at least two complex and nuanced topics: the certainties and uncertainties of climate science and the technoeconomic realities of energy systems. Experts in those subjects have a responsibility to communicate their understanding to non-experts clearly, completely, and without bias.

Expertise in energy systems resides largely in the private sector, where it is essential to providing the reliable and affordable energy services that are the lifeblood of society. Understanding is therefore continually refined and tested by the discipline of the marketplace. In contrast, climate science expertise is found largely in the non-profit realm of universities and government laboratories and so has a more academic character.

In recent decades, climate science has engendered passion and emotion. Indeed, some younger climate scientists have gone into the field to "save the planet." Further, the field of climate science has been politicized by NetZero mandates. It is then not surprising that objectivity can suffer when climate scientists communicate their understanding to non-experts. This lack of objectivity usurps the public's right to make informed choices and undermines their confidence in the scientific enterprise.

In 1980, then-President of the National Academy of Sciences Philip Handler identified the problem in an editorial (Handler 1980) that resonates eerily four decades later:

Difficulty arises in the scientific community from confusion of the role of scientist *qua* scientist with that of scientist as citizen, confusion of the ethical code of the scientist with the obligation of the citizen, blurring the distinction between intrinsically scientific and intrinsically political questions. When scientists fail to recognize these boundaries, their own ideological beliefs, usually unspoken, easily becloud seemingly scientific debate.

1.4 When Peer Review Fails

Peer review of reports like IPCC and NCA products is not a silver bullet that guarantees quality. The peer review process for these reports differs in some important respects from traditional peer review in academic journals. First, during the open review phases of early NCA drafts reviewers are volunteers who self-select what parts of the report to read, whereas the editors of academic journals editors recruit reviewers with relevant expertise and assign them to specific papers. As a result, there is no guarantee at that stage that any particular section of an NCA report was reviewed by anyone, ~~WHAT ABOUT THE NASEM REVIEW?~~ let alone by someone with a perspective that differs from the authors. In fact, many potential reviewers have given up over the years because their input has systematically been ignored. The introduction of a NASEM review stage is at best a partial remedy for this. However, Second, NCA authors have near complete authority whether to accept or reject review comments. By contrast, the Editor of an academic journal mandates the author to respond, respond, and the reviewer and Editor assess its adequacy. And third, Finally, the work of an NCA chapter author team is guaranteed to be published, whereas academic journals routinely reject papers that do not pass review.

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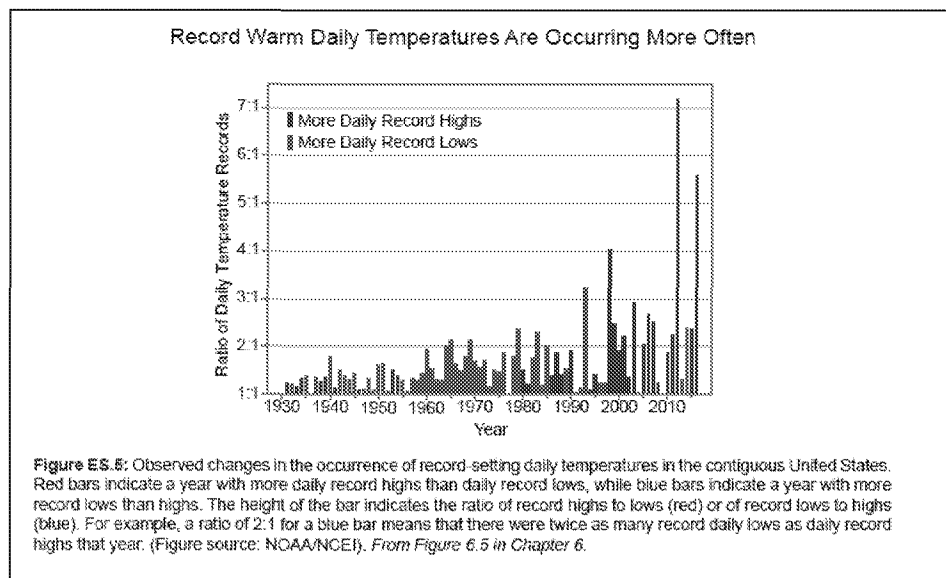
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These points are important to bear in mind because some readers might dismiss any criticism of NCA products out of hand on the grounds that they were "peer reviewed". But the test of a report is whether its contents are a valid representation of the available evidence. Here we give an example in which NCA4 gave prominence to a figure that completely misrepresented the underlying data and which evaded peer review to do so. Further details can be found in Koonin (2024).

As shown in CWG25 Section 6.3 the number of heat extremes in the U.S. peaked in the 1930s and has declined ever since. Considering cold and hot extremes together the U.S. the U.S. climate has become more moderate over time. NCA4's Part I ~~{[HYPERLINK "https://science2017.globalchange.gov/"]}~~, CCSP) says (prominently and with *Very High Confidence*) on Page 19 of the Executive Summary:

There have been marked changes in temperature extremes across the contiguous United States. The number of high temperature records set in the past two decades far exceeds the number of low temperature records.

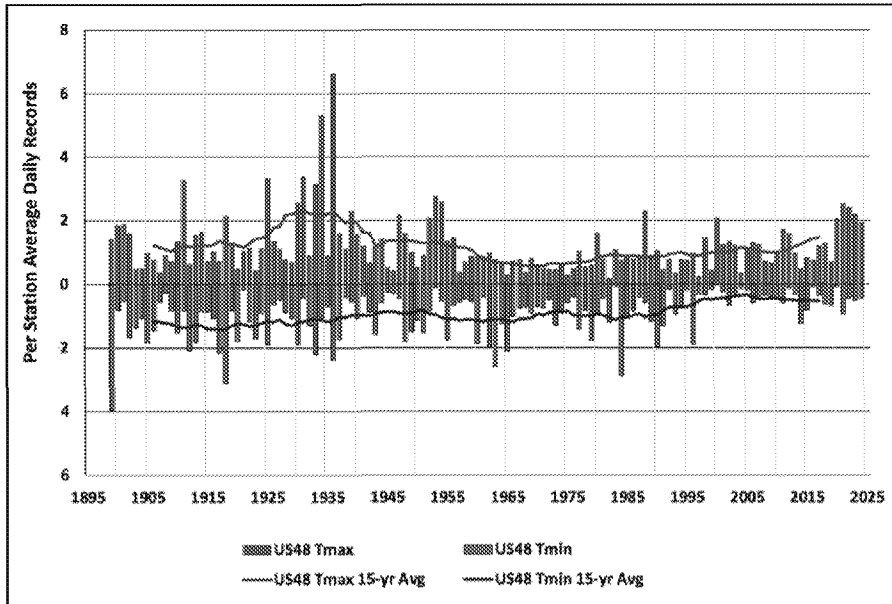
and offers this figure in support:



The figure appears to validate the claim that record warm daily temperatures are occurring more often. But the underlying data do not. Rather, they show that extreme heat in the U.S. peaked in the 1920s and 1930s and declined thereafter, as supported by Figure 6.4 deep within the CSSR itself (reproduced in our Section 4.2 below).

Figure ES.5 does not even show what its title implies, as it displays not simple counts of cold and warm extreme events, but rather ratios of the two counts. In fact, both types of extremes declined over the sample interval, but cold events declined more than warm events, so the ratio of warm extremes to cold extremes increased. By graphing the ratio instead of counts, NCA4 creates a visual impression opposite to what is in the data.

Figure 6.3.3 of CWG25 (reproduced below) shows the results of a proper analysis of the data – defining each record as the singular extreme in the sample interval, displaying numbers of warm and cold records separately, and beginning the analysis in 1899 rather than 1930. It makes evident the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. The increased heat of the past five years is too brief to be deemed climatically significant and, in any event, occurred after the CSSR was published in 2017. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the heat records were achieved in the last quarter, which is consistent with statistical expectations. As a result, the ratio of heat to cold extremes shown in Figure ES.5 of the CSSR explodes in recent decades. The overall reduction in numbers of both cold and hot extremes over the past century indicates a climate *less* prone to extremes, in sharp contrast to the message of NCA4 Figure ES.5.



Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature. Source: CWG25 Figure 6.3.3.

The National Academies' expert review panel [[HYPERLINK "https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report"](https://www.nap.edu/catalog/24712/review-of-the-draft-climate-science-special-report)] the discussion of temperature extremes in a [[HYPERLINK "https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf"](https://biotech.law.lsu.edu/blog/Draft-of-the-Climate-Science-Special-Report.pdf)] of the CSSR. In reference to the CSSR's Key Finding 2 of Chapter 6, they said:

Further, it is difficult to understand how a statement that includes increases in extreme warmth can be associated with a high confidence or extremely likely statement, given that most of the graphics in this chapter show a decrease in extreme warmth in the historical record.

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The Federal official in charge of the CSSR (Michael Kuperberg, Executive Director of the USGCRP) [[HYPERLINK "https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf"](https://science2017.globalchange.gov/PDFs/CSSR-NASresponse_110217.pdf)] to the Academies' review by noting that

Almost every recommendation from the NAS was incorporated [in the final version]...and a new figure was added on changes in record high and low temperatures

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The “new figure” referred to is the Figure ES.5, which did not appear in the draft reviewed by the Academies’ panel. It seems unlikely that the Academies panel ever saw that figure because they surely would have commented if they had and it wouldn’t have survived to publication. And the figure’s problems were evidently not flagged (or were ignored) in the subsequent internal government reviews.

With this background we now present our critique of NCA5.

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2 NCA5 OVERVIEW CHAPTER: HYPERBOLIC ADVOCACY LANGUAGE AND UNSCIENTIFIC TONE

NCA5 Chapter 1, "Overview", holds a prominent place in the Report since it summarizes the entire report and is the only section that many will read. Although the later chapters of NCA5 contain much sound scholarly content, Chapter 1 is marred by an activist tone and language that aggressively promotes mitigation policies. As such, this chapter adds an imprimatur of scientific authority to oversimplified declarations of opinion about public policy. Many examples can be cited; here we note a few that are particularly egregious.

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Chapter 1 opens as follows:

The more the planet warms, the greater the impacts. Without rapid and deep reductions in global greenhouse gas emissions from human activities, the risks of accelerating sea level rise, intensifying extreme weather, and other harmful climate impacts will continue to grow. Each additional increment of warming is expected to lead to more damage and greater economic losses compared to previous increments of warming, while the risk of catastrophic or unforeseen consequences also increases.

This statement presupposes that all warming is anthropogenic, that all warming is bad and causes economic damage, and that warming intensifies extreme weather. Such sweeping generalizations go well beyond what science has or can establish. The statement also refers to growing risks without saying whether they were large to begin with-- a small risk that grows may still be a small risk, and a large risk may be only incrementally worsened. A scientifically-sound version of this paragraph would instead say something like the following:

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The Earth is warming because of a combination of natural and anthropogenic influences. This warming will generate a mix of benefits and harms that varies by region, to which society should be prepared to adapt. Some types of extreme weather have worsened recently, while others have not changed or have even declined in intensity. Reducing emissions of greenhouse gases might slow the warming although such policies have proven to be costly and disruptive, so any climate actions to be weighed against the potential benefits.

On the next page the Overview states:

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Each additional increment of warming leads to greater risks [here it lists 7 key components of society including food security and the economy]... Without deeper cuts in global net emissions, climate risks to the US will continue to grow... Action to limit future warming and reduce risks can have near-term benefits and opportunities: low-carbon energy jobs, Improved air quality, Health benefits, Economic benefits..."

The authors write as if climate policy does not involve trade-offs and all measures to reduce future warming will be effective and beneficial. But the vast body of scholarship on climate science and economics does not support such simplistic claims. Not every additional increment of warming leads to economic harms; in fact, NCA5 Chapter 19 acknowledges that there will also be benefits. Nor is

climate policy guaranteed to create jobs or benefit the economy; in many cases it has done the opposite. Such deceit is a disservice to policymakers.

Pages 8 and 9 of the Overview promote renewable energy options by noting, correctly, that the leveled costs of wind/solar generation have fallen sharply since 2010, and so offers this rationale for pursuing deep emission reductions:

Recent growth in the capacities of wind, solar, and battery storage technologies is supported by rapidly falling costs of zero- and low-carbon energy technologies, which can support even deeper emissions reductions. For example, wind and solar energy costs dropped 70% and 90%, respectively, over the last decade, while 80% of new generation capacity in 2020 came from renewable sources.

Yet it has long been known that intermittent renewables generation must be supplemented by dispatchable generation to meet grid reliability standards, and that doing so (e.g., through natural gas, fission, or storage) significantly increases the cost of electricity. Further, there are yet unmet synchronization challenges in transmission grids with heavy penetration of wind and solar power. Here again it is advisory malpractice not to acknowledge these facts.

Page 14 of the Overview presents future emission scenarios with the following description: "Climate modeling experts develop global climate projections for a range of plausible futures." The word "plausible" is applied to all of the scenarios. The accompanying Figure includes both SSP3-7.0 and SSP5-8.5, the latter reaching the same radiative forcing as RCP8.5. The Figure does not compare observed emissions with previous projections nor does it caution readers that SSP3-7.0 and SSP5-8.5 are extreme worst case scenarios that, like RCP8.5, have been heavily criticized in the scientific literature (CWG25 3.2.1). By describing the entire envelope of emission projections as "plausible" the report opens the door to later presenting impacts associated with extreme and implausible emission scenarios as part of a baseline "business-as-usual" future.

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Page 17 of the Overview introduces the discussion of risks from extreme weather events by saying "Harmful impacts from more frequent and severe extremes are increasing across the country." This creates the impression that disaster losses are driven by trends in extreme weather. While the section goes on to acknowledge that some of the increase is due to increases in the value of assets at risk it then invokes the NOAA Billion Dollar Dataset as evidence of extreme weather getting worse. Scientists have shown that this is an invalid metric (CWG 10.2) since it measures the growth of the economy not the frequency of extreme weather, and indeed NOAA has recently withdrawn the data product (Pielke Jr. 2024, 2025). Even though it was still distributed by NOAA at the time of the NCA5, the report authors should have assessed it skeptically and seen that it was unfit for the purpose of measuring climate trends.

Page 23 of the Overview states, in large font:

Climate changes are making it harder to maintain safe homes and healthy families; reliable public services; a sustainable economy; thriving ecosystems, cultures, and traditions; and strong communities.

It is pointless to try to evaluate this statement on scholarly grounds; it is self-evidently hyperbolic. This kind of language doesn't belong in a scientific assessment report. Its prominent inclusion points not only to the willingness of NCA5 authors to promote alarm, but also the ineffectiveness of the review process in not ensuring such statements are removed.

3 OVERCONFIDENCE WHEN STATING CONCLUSIONS

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3.1.1 Inflated certainty levels

Overconfidence in stating conclusions is an endemic problem in NCA5. The authors frequently make sweeping generalizations without appropriate caveats or acknowledging uncertainties. The overconfidence begins with inflated language to describe certainty levels.

NCA5 uses specific terms to convey information about scientific confidence associated with important finds, observations and projections. The Front Matter of NCA5 states that

confidence in a finding is based on the type, amount, quality, strength, and consistency of evidence; the skill, range, and consistency of methods to detect, evaluate, attribute, and interpret climate trends; and the degree of agreement across scientific information sources.

and Table 1 from the Front Matter provides calibrated language for confidence assessment:

Very high:	Strong evidence (established theory, multiple sources, well documented and accepted methods, etc.). High consensus
High:	Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.). Medium consensus
Medium:	Suggestive evidence (a few sources, limited consistency, methods emerging, etc.) Competing schools of thought.
Low:	Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.). Disagreement or lack of opinions among experts.

This terminology is inflated: *high confidence* with just moderate evidence and medium consensus; *medium confidence* with only suggestive evidence and competing schools of thought. This inflation in terminology leads to overconfidence in conclusions.

Even with this inflated terminology, NCA5 further inflates the confidence level of many of its conclusions to well beyond what the IPCC has concluded with more thorough justification, and also by incorrectly applying its own standards. The following example is the conclusion about anthropogenic influence on climate change, arguably one of the most important scientific statements of the report.

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Key Message 3.1 Traceable Account states:

There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have unequivocally caused *all* global warming observed over the industrial era.

while the corresponding statements from IPCC AR5 and AR6 are

AR5: It is *extremely likely* that *more than half* of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in greenhouse gas concentrations and other anthropogenic forcings together." (IPCC, 2013)

AR6: The *likely* range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C. It is *likely* that well-mixed

GHGs contributed a warming of 1.0°C to 2.0°C, other human drivers (principally aerosols) contributed a cooling of 0.0°C to 0.8°C, natural drivers changed global surface temperature by -0.1°C to +0.1°C, and internal variability changed it by -0.2°C to +0.2°C. It is *very likely* that well-mixed GHGs were the main driver of tropospheric warming since 1979.

The IPCC AR5 and AR6 statements provide likelihood assessments but not a confidence level. While NCA5 claims with *very high confidence* that fossil fuels have unequivocally caused *all* global warming, AR5 refers to "*more than half of the observed warming*" and AR6 provides a more nuanced statement that relates to a *likely* range of warming contributed to by human drivers.

~~Quite separately we note that the attribution of various changes to "climate change" is misleadingly ambiguous. Because NCA5's Glossary defines "climate change" as a change in climate for any reason, the statement is a tautology and so the attribution is superfluous. But because the popular perception of climate change is anthropogenic, its gratuitous inclusion effectively attributes the changes to greenhouse gas emissions.~~

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2.3.2 Overstating findings in underlying sources

Although we did not do a detailed audit of NCA5's use of source material, spot checks turned up evidence of a pattern of overstatement.

Chapter 2 page 11 reports on an increase in precipitation in some areas and attributes it to "human caused climate change":

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Many eastern regions of the country are getting wetter (Figure 2.4). Average annual precipitation from 2002-2021 was 5%-15% higher relative to the 1901-1960 average in the central and eastern US, a trend attributable to climate change.

~~Note that the attribution of various changes to "climate change" is misleadingly ambiguous. Because NCA5's Glossary defines "climate change" as a change in climate for any reason, the statement is a tautology and so the attribution is superfluous. But because the popular perception of climate change is anthropogenic, its gratuitous inclusion effectively attributes the changes to greenhouse gas emissions. The NASEM review (pp. 23-24) commented on this problem but their comment was ignored.~~

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~~Note that this change metric in NCA5 Figure 2.4 is a non-standard metric; we will discuss NCA5's inconsistent choices of time scales of analysis below. The claims were attributed to the following paper: Knutson and Zeng (2018).~~

- ~~• Knutson, Thomas and Fanrong Zeng (2018) "Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends" *Journal of Climate* 31(12) [HYPERLINK "https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml"]~~

But Knutson and Zeng did not say these things. They examined linear trends over 1901 - 2010, 1951 - 2010 and 1981 - 2010. They did not compare average rainfall over 2002 - 2021 to average rainfall over 1901 - 1960, if only because their study was published in 2018. For 1981-2010, they noted stronger trends in some areas but cautioned that such changes are consistent with natural variability, and they did not claim attributable trends were observed over the United States:

Observed annual precipitation trends over the recent 30-yr period 1981–2010 ([HYPERLINK "https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml" \l "fig5"]) have generally stronger magnitudes (in mm yr⁻¹ decade⁻¹) than observed trends for 1901–2010 or 1951–2010. This is as expected since trends over a shorter period have stronger potential for occurrence of pronounced temporary trends due to internal variability alone. Only 9% of the analyzed area has detectable and attributable anthropogenic influence (categories -3, -2, +2, +3), which represents less than one-third of the fractional areal coverage of such trends for 1901–2010 (29%). ... Eight percent of the analyzed area has attributable anthropogenic *increases* (categories +2, +3), including parts of eastern Europe, northern Asia, northern Australia/Maritime Continent, and tropical Africa.

As another example of overstating findings, NCA5's Chapter 2 page 18 states

There is robust evidence that human-caused warming has contributed to increases in the frequency and severity of the heaviest precipitation events across nearly 70% of the US.

This is allegedly attributed to two papers Diffenbaugh *et al.* (2018) and Kirchmeier-Young and Zhang (2020).

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- ~~Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. [HYPERLINK "https://doi.org/10.1126/sciadv.aao3354"]~~
- ~~Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308–13313. [HYPERLINK "https://doi.org/10.1073/pnas.1921628117"]~~

Diffenbaugh *et al.* presented ratios of observed occurrences of extreme events to simulated occurrence rates in CMIP6 models run with only natural forcings. They report that for 79% of the U.S. extreme rainfall event frequencies are currently higher than in model simulations, and the ratio of occurrences will rise under future warming simulations. This is not "robust" evidence of anthropogenic influence since it requires readers to assume that climate models provide accurate simulations of regional precipitation patterns, something that even IPCC AR6 admits is uncertain (AR6 WGI SPM Box SPM 1.2, SPM Section C.1.3).

Kirchmeier-Young and Zhang looked at extreme 1- and 5-day events in North America and, using three GCMs, found

A signal of combined anthropogenic and natural external forcing can be detected in the intensification of extreme precipitation at the continental scale over North America. In some cases, this intensification can be attributed to human influence specifically.

However, they noted large differences among the three models in their simulated precipitation changes. Also, two of the three models failed to yield attribution for 5-day events for the North America mean. In other words the models disagreed on whether the observed changes were due to anthropogenic activity. Both cited references utilized the implausible RCP8.5 scenario and began

their “historical” observational records only in 1961. Here again this is not “robust” evidence, it is merely suggestive, particularly since other studies have found natural variability predominant.

2.3.3 Technical example: Emergent constraints

Some of the overconfidence expressed by NCA5 arises by omitting discussion of counterevidence in the peer reviewed literature. An example is the topic of “emergent constraints”. Chapter 3 page 17 invokes this concept to support its claim that key uncertainties have been reduced:

An approach to reduce uncertainty in climate change projections has matured over the past decade. It is known as “emergent constraints.” The term refers to strong statistical relationships between highly uncertain future climate parameters and observable trends or variations in the current climate, along with a physical explanation of this relationship.

Emergent constraints appeared in the climate modeling literature as an attempt to tie GCM behavior to climate observations in hopes of generating insight into real-world equilibrium climate sensitivity to a doubling of carbon dioxide (ECS). Climate models exhibit a wide range of ECS values. The idea of emergent constraints is to examine whether the models with shared sensitivity values also share a common representation of some climate process (usually related to clouds) that might indirectly influence ECS. Suppose, for instance, that in low-ECS models the total cloud fraction in the tropics is strongly correlated with that in the southern midlatitudes but in high-ECS models the correlation is weak. Then researchers could examine whether the observed correlation is strong or weak and draw a conclusion about which type of model, and therefore which ECS value, is more likely.

A problem in the emergent constraint literature is that there has been a proliferation of proposed correlations with little physical motivation. As shown by Schlund *et al.* (2020) many emergent constraints patterned on CMIP5 models (Coupled Model Intercomparison Project No. 5, used for the IPCC 5th Assessment Report) failed to work on CMIP6 models (used for the IPCC 6th Assessment Report) models (Schlund *et al.* 2020). In other words, the observed correlations in CMIP5 models between ECS and cloud processes failed to show up in CMIP6 models, indicating that they were likely spurious rather than clues to physical processes governing the Earth climate system. As a result, was that emergent constraints estimated from on CMIP5 models widened increased the range of estimated uncertainty of ECS values when applied to CMIP6 models, rather than narrowing it as intended and as claimed by NCA5.

Schlund *et al.* summarized the problem as follows [boldface used for emphasis]

In this study, we systematically analyze 11 published emergent constraints on ECS that have mostly been derived from models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5) project... The focus of the study is on testing if these emergent constraints hold for [Earth System Models] participating in the new Phase 6 (CMIP6). Since none of the emergent constraints considered here have been derived using the CMIP6 ensemble, CMIP6 can be used for cross-checking of the emergent constraints on a new model ensemble. **The application of the emergent constraints to CMIP6 data shows a decrease in skill and statistical significance of the emergent relationship for nearly all constraints, with this decrease being large in many cases.** Consequently, the size of the constrained ECS ranges (66% confidence intervals) widens by 51% on average in CMIP6 compared to CMIP5.

Yet NCA5 described the use of emergent constraint analysis as a great “advance” that reduced uncertainty.

3.4 RELIANCE ON AD-HOC SHORT TIME SCALES PERIODS FOR TREND ANALYSIS

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In CWG25 Chapter 6 we discussed the need for care in the choice of time scale when making claims about trends in extreme weather. We provided examples from analysis of river flooding, heatwaves, and extreme precipitation to show how assertions about apparent trends based on short data sets fall apart when looking at longer versions of the same data sets. Here are some examples of this problem from NCA5. Here we elaborate on these examples to illustrate the general point that NCA5 made inconsistent and *ad hoc* choices about time scales of analysis, weakening the validity of their conclusions.

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McKittrick and Christy (2019) showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s, depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017). In CWG25 Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

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3.4.1 Average and Extreme Precipitation

McKittrick and Christy (2019) showed that apparently significant positive trends in U.S. average and extreme precipitation over the NCA4 interval (1901 – 2016) disappeared on longer samples (extending back as far as the 1840s, depending on location) or on a shorter interval coinciding with the final 40 years of the data then available (1978 – 2017). In CWG25 Section 6.4 we presented analyses of updated data for the same locations (and many others), in all cases finding both considerable regional heterogeneity and that trends detectable on one time scale are often not detected on longer or shorter time scales. These findings argue against simple attribution of changes to anthropogenic influences.

Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

NCA5 did not continue the NCA4 precedent of using the post-1901 interval as the time scale for its precipitation discussion; instead it refers to changes “since the 1950s”; NCA5 Figure 2.8 suggests 1958 as might be the intended start date. Under Key Message 2.2 “Extreme Events Are Becoming More Frequent and Severe” (p. 2-16) NCA5 states (p. 2-18):

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Rainfall is becoming more extreme

Since the 1950s, there has been an upward trend in heavy precipitation across the contiguous US. This increase is driven largely by more frequent precipitation extremes, with relatively smaller changes in their intensity.

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In addition to our concerns that inferences about trends are contingent on choice of time scale, we cannot reproduce the finding that positive trends are observed in extreme precipitation across all CONUS regions. For the present report we have extended the data used in CWG25 (McKittrick and Christy 2025) analysis even further to include 141 stations across the US in the Pacific Coast, Midwest, Northeast and Southeast regions (Christy 2025). We provide details in Appendix 3; here we note merely that once again, many post-1950 trends are positive but statistically insignificant depending on the measure of extreme precipitation. It is possible to find location trends that support the NCA5 position, such as the Southeast post-1950, but these results are not robust to selecting longer or shorter time scales of analysis nor do they generalize across all regions. Data from 1950 to 2024 yields many indications of increased average and extreme precipitation at individual stations and region-wide averages. But when using the entire data set (back to the 1890s or earlier, depending on location) or the later subset (1980 to 2024) the trends become smaller, in many cases they become statistically insignificant, and occasionally they even change sign. Only in the Northeast region are the post-1950 trends robust to focusing on trends during the post-1980 interval.

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The following is a more accurate summary of what U.S. data show.

There are regionally heterogeneous changes in average and extreme precipitation. Positive trends in annual average rainfall and extreme events (defined either as the annual maximum or the number of exceedances of the 99th percentile value) are generally weak or non-existent when looking at samples exceeding 130 years in length. Significant trends can be found when beginning the sample in the 1950s although in most cases the trends weaken and become insignificant when looking at the post-1980 interval. This makes attribution of changes in precipitation to anthropogenic warming difficult.

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3.24.2 Heatwaves

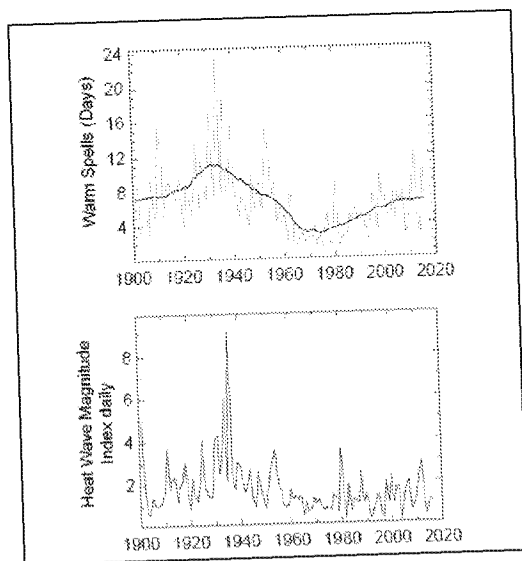
In contrast to NCA5, NCA4 examined heat extremes across the entire 20th century, pointing out that peak heat wave activity was reached in the 1930s and has decreased since then, and that recent increases are confined to areas west of the Rockies:

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[The] warmest daily temperature of the year increased in some parts of the West over the past century, but there were decreases in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net decrease, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]).

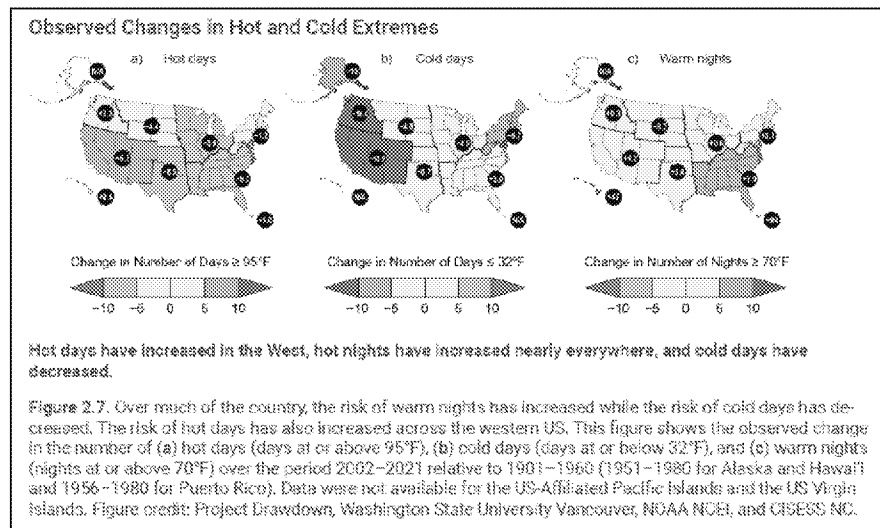
Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, heat wave magnitude reached a maximum in the 1930s.

(NCA4 pp. 190-191)



U.S. Heat waves since 1900. Source: NCA4 Figure 6.4

Contrast this careful and factual language with NCA5 Key Message 2.2: "Extreme Events Are Becoming More Frequent and Severe." This blanket statement is followed by NCA5 Figure 2.7 (reproduced below) which shows the number of hot days, cold days and warm nights (respectively in panels a—c) over the period 2002-2021 compared to 1901-1960. [Presumably these are annual counts, although not stated in the caption.]



Close inspection shows that this figure contradicts the NCA5 Key Message with respect to heatwaves and instead reinforces the position of NCA4. Notwithstanding Key Message 2.2 the leftmost panel in Figure 2.7 above shows that over most of CONUS the number of extreme heat days has decreased in recent decades compared to the prior century.

The accompanying discussion in NCA5 becomes convoluted as it appears to be aimed at supporting the Key Message despite the contrary evidence. NCA5 chapter 2 elaborates on Key Message 2.2 by saying (page 16):

Observations show an increase in the severity, extent, and/or frequency of multiple types of extreme events. Heatwaves have become more common and severe in the West since the 1980s (*high confidence*).

But while it mentions the increase in hot days in the wWest it NCA5 fails to mention WHAT DECLINE the decline decrease elsewhere everywhere east of the Rockies. Instead, it says oOn the next page (page 17) it raises the comparison to the 1930s then switches to discussing global counts: THIS POINT IS UNCLEAR

By some measures, the most extreme heatwaves on record in the United States occurred during the Dust Bowl era of the 1930s. ... Globally such heatwaves are becoming more frequent, and in recent decades the western United States has been following those trends.

The reference to a global trend seems to be an attempt to tie heatwaves to anthropogenic climate change. But the obvious question, unaddressed by NCA5, is why one region follows the global pattern of increasing heatwaves it WHAT?? holds for only part of the U.S. while most of the country is trending in the opposite direction. These issues are addressed in Chapter 6 of CWG25, demonstrating that the range and magnitude of extreme temperatures (10s of degrees) are driven more by natural variability than by the small anthropogenic forcing. The analysis in CWG25 shows that for both (a)

hot days ($\geq 95^{\circ}\text{F}$) and (b) number of days in heatwaves, the current decade is no hotter than a century ago ~~in the U.S.~~ Thus, the NCA5 claim that “multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades,” is simply false when expanding the temporal and spatial domains to encompass all available data (Chapter 6 and Figure 6.3.6 of CWG25).

NCA5 then pointed to the dramatic Pacific Northwest heatwave of 2021. CWG2025 Section 8.6.1 discussed this event in detail, reviewing the multiple peer reviewed studies that explained the unusual meteorological context was unrelated to human-caused climate change, a point omitted from the NCA5 discussion.

NCA5 finally addresses the declining heatwave trend in CONUS east of the Rockies but attempts to reframe it by focusing on urban warm spells.

[The] number of very hot days has actually decreased across the central and eastern regions due to summer cooling trends in the region (Figure 2.7; Ch. 22). This does not, however, mean the central and eastern US are not affected by heat. The impacts of extreme high temperatures are more severe if such conditions persist for several days, and overall, multiday heatwaves have become hotter, more frequent, larger, and longer lasting in recent decades. Across 50 large US cities, the US Global Change Research Program heatwave indicator ([[HYPERLINK "https://www.globalchange.gov/indicators/heat-waves"](https://www.globalchange.gov/indicators/heat-waves)]) shows that the average number of heatwaves has doubled since the 1980s, and the length of the heatwave season has increased from about 40 days to about 70 days.

We discussed ~~this issue~~ ~~WHAT ISSUE~~ part of NCA5 in CWG25 Section 6.3. The figure referenced by NCA5 uses an *ad hoc* definition of heat wave, namely two consecutive days with minimum nighttime temperatures above the 85th percentile, and an *ad hoc* time scale which begins in the 1960s, the coldest decade in the last century, thus suppressing any comparison to the 1930s. Further, nighttime temperatures in urban areas have increased faster than daytime temperatures (which NCA5 acknowledges), but this is a signature of urban heat islands and not a good metric of climate change. CWG25 noted as well that the occurrence of hot days ($\geq 95^{\circ}\text{F}$) has recently increased in the West, but declined in the remainder of the country, and in the nationwide average, since 1899.

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45 INADEQUATE TRACEABLE ACCOUNTS

NCA3 began the practice of including a section on Traceable Accounts at the end of each chapter. This is the description from NCA5:

Each chapter concludes with a section entitled Traceable Accounts, which provides information on the overall process used to develop the chapter as well as a separate Traceable Account section for each Key Message. These Traceable Accounts describe the supporting evidence behind each Key Message, the process and rationale authors used in reaching their conclusions, and the author team's expert assessment of the confidence in and, where applicable, likelihood of these conclusions. As such, Traceable Accounts provide information about the state of the science, document sources of uncertainty, identify research gaps, and allow traceability to data and resources.

The Traceable Accounts for each Key Message includes the following sections:

- Description of Evidence Base
- Major Uncertainties and Research Gaps
- Description of Confidence and Likelihood

The Traceable Accounts could have addressed in principle address the statutory requirement that the NCA discuss scientific uncertainties. They could also help satisfy the Executive Order for Restoring Gold Standard Science by addressing reproducibility, transparency, communication of error and uncertainty, and skepticism of findings and assumptions. However, the Traceable Accounts in NCA5's Chapters 2 and 3 (the only chapters investigated here) are uneven, often superficial and noninformative/uninformative.

An example of a deficient Traceable Account is NCA5's -Key Message 2.2: "Extreme Events are Becoming More Frequent and Severe". The "Description of the Evidence Base" offers two paragraphs, the first summarizing the findings and the second generically describing the types of data that can be used for storms. "Major Uncertainties and Research Gaps" focuses on the uneven distribution across U.S. populations due to differences in exposure and vulnerability. -The only limitations in data referred to are the lack of a long-term record of lightning and the lack of homogenized daily and hourly temperature data apart from reanalysis products.

But the most astonishing deficiency is in the "Description of Confidence and Likelihood." One of the statements in Key Message 2.2 is:

Hurricanes have been intensifying more rapidly since the 1980s (high confidence) and causing heavier rainfall and higher storm surges (high confidence).

The Description of Confidence and Likelihood includes the following statement:

Basic physical understanding and climate models both provide robust explanations for the links between climate change and observed changes in these extremes: this is why the authors also have high confidence that storms are delivering more rainfall and high confidence that storm surges are becoming higher.

No reference to journal publications or a specific data set is made anywhere in the Chapter regarding hurricane-induced precipitation or storm surge to support this *high confidence* conclusion.

The Traceable Accounts for the various Key Findings of Chapter 3 have some substantial inconsistencies. Consider

Key Message 3-1: Human activities have caused global warming.

Confidence and Likelihood: "There is *very high confidence* that emissions of GHGs from human activities, fossil fuel use in particular, have *unequivocally* caused all global warming observed over the industrial era. There is also *very high confidence* that changes in natural climate drivers have had globally small and regionally variable long-term effects over this period."

The Uncertainties section addresses only uncertainties in radiative forcing by greenhouse gases. In contrast, the Traceability Analysis of Key Message 3-4 ("Humans Are Changing Earth System Processes") is arguably the most scientifically credible text in the entire Chapter raises the problem that relatively little is known about the role of natural variability at the regional scale. From its Description of Evidence Base:

In the last decade, there has been increasing recognition of the role of regional-scale natural variability in the past and future evolution of climate, as well as the fact that regional natural variability signals can be competitive with forced anthropogenic signals.

And from its Major Uncertainties and Research Gaps:

For example, the true natural variability of the climate system on decadal to centennial timescales could be larger than what we estimate from GCMs, which would further increase the irreducible uncertainty stemming from natural variability.

These statements are among the most scientifically credible in the entire NCA5 and they directly undercut the confidence assigned to Key Message 3-1.

There is also a generic problem in tracing NCA5's Traceable Accounts. The Front Matter of NCA5 states:

Each figure and some tables are accompanied by a metadata survey, which can be accessed in the online version of the report by clicking on the eyeball icon above the figure or table (see the table below for explanations of additional icons used throughout the report). The metadata survey describes data sources, figure or table development methods, copyright information, and other important documentation.

Upon clicking on the eyeball icon above a particular figure, does not reveal the metadata information, instead a "Contact Us" email appears, addressed to the USGCRP. No attempt was made to send a email to elicit the Metadata information, but This is clearly an inadequate way to archive the metadata information. It is clear that this information is not readily accessible online.

In summary, the Traceable Analyses examined here, with few exceptions, fail to meet the stated objectives set forward by the NCA.

|

56 OVEREMPHASIS ON EXTREME SCENARIOS

To respond to the GCRA mandate to “project major trends for the subsequent 25 to 100 years,” NCA5 relies on projections of future climate change based on estimates of future emissions (the so-called SSP scenarios) and/or specified levels of radiative forcing (the RCP scenarios). For the most part, NCA5 uses scenarios developed for the IPCC Assessment Reports.

In CWG Section 3.2.1 we presented a critical assessment of past and current IPCC scenario envelopes, showing that they have tended to overshoot observed emissions. The IPCC AR6 published in 2021 stated that “The likelihood of high-emission scenarios like RCP8.5 and SSP5-8.5 is considered low in light of recent energy sector developments.” and that same year UN Climate Negotiators (COP) stopped using scenarios above 4.5.

NCA5 makes the following observations about the scenarios they use:

NCA5 authors were advised to assess the full range of scenarios available. (Front Matter)

Scenarios of future emissions and land-use change are developed as plausible alternatives, but no relative likelihood is attached to them. Some recent studies, however, have argued that the highest scenario, SSP5-8.5, is no longer plausible without a reversal of current trends in the adoption of renewables and energy efficiency. (Key Message 3.3 Traceable Analysis)

Despite acknowledging the issue, NCA5 otherwise ignored the problem. A keyword search of NCA5 of mentions of RCP/SSP scenarios finds over 50% referred to the extreme emissions scenarios RCP8.5/SSP5-8.5. Further, nine of NCA5 figures (5.2, 6.9, 7.4, 11.3, 14.6, 22.13, 22.19, 27.9, 29.13) included *only* the 8.5 scenarios.

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The problem of relying on extreme scenarios is particularly acute for NCA5’s sea level rise projections. The sea level rise scenarios used in NCA5 do not relate directly to the SSP emissions scenarios, but rather to specified amounts of sea level rise by 2100. Table 4 of NCA5’s “Guide to Using this Report” reproduced below shows that Low relates to 0.3 m (0.98 feet), Intermediate-Low relates to 0.5 m (1.64 feet), Intermediate relates to 1.0 m (3.28 feet), Intermediate-High relates to 1.5 m (4.92 feet), and High relates to 2.0 m (6.56 feet).

Table 4. Descriptive Terms for Common Sea Level Rise Scenarios Used in NCA5						
Future global mean sea level rise and sea level rise along United States coastline are shown for five scenarios in feet (and meters), relative to a 2000 baseline. The US values shown in the right half of the table are averaged across the US coastal regions, including the contiguous US, Alaska, Hawaii and the US-Affiliated Pacific Islands, and the US Caribbean. The national values shown in the table differ substantially from regional values. For example, sea level rise is higher in the Gulf Coast and lower or even negative in some parts of Alaska. In the next 30 years (2020–2050), sea level along the contiguous US coasts is expected to rise 0.92 feet (0.28 m), the same amount of sea level rise observed over the last 100 years (1920–2020). See Chapter 9 for regional sea level information. Adapted from Sweet et al. 2022. ¹						
Sea Level Rise Scenario Descriptor	Global Mean Sea Level			United States		
Year	2050	2100	2150	2050	2100	2150
Low	0.49 (0.15)	0.98 (0.3)	1.31 (0.4)	0.59 (0.18)	0.98 (0.3)	1.64 (0.5)
Intermediate-Low	0.66 (0.20)	1.64 (0.5)	2.62 (0.8)	0.75 (0.23)	1.64 (0.5)	2.95 (0.9)
Intermediate	0.92 (0.28)	3.28 (1.0)	6.23 (1.9)	0.89 (0.27)	3.28 (1.0)	6.89 (2.1)
Intermediate-High	1.21 (0.37)	4.92 (1.5)	8.86 (2.7)	1.12 (0.34)	4.92 (1.5)	8.86 (2.7)
High	1.41 (0.43)	6.56 (2.0)	12.14 (3.7)	1.38 (0.42)	6.56 (2.0)	12.46 (3.8)

Table 4 from the Front Matter of NCA5

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Considering only projections representing processes quantified with at least medium confidence, IPCC AR6 assessed global mean sea level projections for 2100 to fall between 0.2 and 1.6 m (5th–95th percentile range). Nevertheless, the range of sea level rise scenarios considered by NCA5 extends to 2.0 m. Further, NCA5 fails to include plausible lower scenarios, such as 0.2 m cited by the IPCC, which also corresponds to the average rate of sea level rise over the past century.

Chapter 9 of NCA5 offers the following predictions of sea level rise:

“Under a range of potential global warming levels, average sea level along US coastlines is *likely* to be between 12 and 20 inches above 2000 sea levels in 2050 (Figure 9.2).”

These values span from the Intermediate scenario to values slightly greater than the High scenario. They can be put into context by considering the [[HYPERLINK "https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level"](https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level)] global sea level rise from 2000–2024, approximately 3.39 inches (0.28 feet). NCA5 is thus projecting a sea level rise during 2025 and 2050 that is 3.5 to 5.8 times the rate observed during 2000–2024, an exceedingly implausible outcome. Chapter 9 further states:

“Looking toward the future, an 11 inch (28 cm) average rise along the contiguous US coastline is expected by 2050 (relative to 2020), with a *likely* range of 9–13 inches.”

...

“There is *high confidence* and it is *likely* that sea levels will rise about 11 inches (likely range of about 9–13 inches) between 2020 and 2050”

In summary, NCA5 presents future sea level rise scenarios that are not directly relatable to either SSP/RCP emissions scenarios nor to global warming levels. The NCA5 scenarios include two scenarios that are higher than the 95th percentile for the extreme emissions scenario RCP8.5 and include hypothesized ice sheet processes in which there is low confidence. Projections to 2050

require rates of sea level rise from 2025 to 2050 that are more than triple the rate observed during 2000-2024. Further, NCA5 ascribes *high confidence* to these sea level rise projections. CWG25 Section 7.3 provides further context for USGCRP projections of extraordinary sea level rise in the next 25 years.

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More generally, NCA5's inclusion, and even focus, on implausible extreme emissions scenarios supports projections of alarming impacts that are very unlikely to be driven by anthropogenic warming.

6.7 INADEQUATE NASEM REVIEW: TO BE ADDED

I THINK WE SHOULD DELETE THIS CHAPTER, IT ISN'T VERY STRONG

The National Academies of Science, Engineering and Medicine (NASEM) undertook a detailed review of the draft NCA5 (NASEM 2023).⁴ While they raised some of the same concerns that we have articulated herein, their review is superficial overall and appears to be written by authors who share many of the biases of the NCA5 team. There is an inordinate focus on social and policy issues (e.g., every chapter is assessed under the heading "Comments on Equity and Justice"), rather than on the underlying science. In our assessment NASEM failed to apply the serious rigor one would expect. A few extracted comments from it will illustrate. Note that NASEM review comments are included here in blue font for reference.

6.17.1 Substantive criticisms by NASEM

- summarize the valid points made by NASEM and check the NCA replies

6.27.2 Failures to challenge NCA5 flaws

NASEM praised Chapter 2, saying:

The chapter [2] meets the requirements of Section 106 of the GCRA.

Yet contrary to the requirements of Section 106, ~~NCA5 Chapter 2~~ did not adequately discuss natural variability let alone assess the full climate record available for quantifying natural variability. Chapter 2 actually minimizes natural variability by claiming (unsubstantiated) skill in attributing recent extremes to human causes. For example NCA5's Chapter 2 Introduction states,

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"...recent advances in attribution science (KM [[HYPERLINK "https://nca2023.globalchange.gov/chapter/3"](https://nca2023.globalchange.gov/chapter/3) \l "key-message-3" \t "_blank"]) mean that the role of climate change in some extreme events can now be quantified in real time. For example, climate change made the record-breaking Pacific Northwest heatwave of June 2021 2° to 4°F hotter, and in 2017 ..."

⁴ National Academies of Sciences, Engineering, and Medicine. 2023. *Review of the Draft Fifth National Climate Assessment*. Washington, DC: The National Academies Press. [[HYPERLINK "https://doi.org/10.17226/26757"](https://doi.org/10.17226/26757)].

CWG25 reviews the expert literature demonstrating that this particular event would have happened with or without climate change and that for CONUS, hot extremes are no more frequent now than they were in the past. NASEM did not challenge the unsubstantiated attribution claims in NCA5.

Notwithstanding NASEM's claim that the Chapter complies with Section 106 of the GCRA, it then acknowledged the absence of discussion of natural variability:

...the discussion and references regarding the role of natural climate variability and its regional differences are missing.

While a nod to natural variability is occasionally found in NCA5, it is usually followed by a "however" to emphasize human influence. One example is the statement just before the claim mentioned above pertaining to extreme event attribution: "There has always been extreme weather, which occurs even in an unchanged climate due to the natural variability of the Earth system. However, recent advances in attribution science (KM [[HYPERLINK "https://nca2023.globalchange.gov/chapter/3"](https://nca2023.globalchange.gov/chapter/3)] \l "key-message-3" \t "_blank")) mean that the role of climate change in some extreme events can now be quantified in real time..."

We pointed ~~o~~ ~~REFERENCE THE SPECIFIC SECTION OF THIS REPORT~~ out (Section 4.2) that the evidence regarding heatwaves directly contradicts Key Message 2.2. NASEM did not mention this, instead it focused on a somewhat esoteric issue of terminology:

"Extreme Events Are Becoming More Frequent and Severe."

Key Message 2.2 is another generally well written key message. However, while the title of this key message includes the word "risk," the key message is exclusively about hazard. The Committee suggests rewriting the key message title to more accurately reflect the discussion on hazards.

The NASEM review appears to accept NCA5's use of short data records because it makes no critical remarks about the failure to assess long time series, except for its observation that the use of short records makes the omission of natural variability that much more of a problem:

It is also important to point out that the influence of natural climate variability becomes particularly strong when the climate trend is computed based on short periods of time or small geographic areas.

This comment was largely ignored in the NCA5 final text.

In sum, while the NASEM review might bestow the Academies' imprimatur on the NCA5 report, it does not necessarily add to its quality for two reasons. As we have demonstrated, the NASEM review falls short in rigor and completeness. And second, the NCA authors are not obligated to follow the NASEM recommendations in crafting their final product.

78 SUMMARY EVALUATION OF NCA5

CHAPTER NEEDS A COMPLETE REWRITE

whether NCA5: (1) complied with the USGCRP's statutory obligation, (2) adheres to the core tenets of Gold Standard Science, and (3) can suitably inform federal climate and energy policy.

The most straightforward evaluation of NCA5 is through its statutory requirements. While it is not within our purview to make definitive rulings on compliance, we believe there are several important aspects to consider when evaluating NCA5 against its statutory requirements. Add text per Seth's letter ...

~~Our expertise in climate science, the foundational area covered by NCA5, allows a different perspective, one that finds the coverage unbalanced and selective. Our review has identified numerous instances where NCA5 falls short of the quality and integrity expected of scientific document of this importance. Furthermore, our examination suggests that the entire process—from the selection of contributing authors to the handling of expert reviews—appears to have been systematically biased toward reinforcing predetermined conclusions and amplifying alarmist messaging rather than presenting a balanced scientific assessment. In short, NCA5 was written to persuade, not inform.~~

~~A third perspective for evaluating NCA5 is that of citizens interested in good policymaking. The changing climate is a legitimate public concern, as are concerns about cost of living, economic growth, employment opportunities, and other socioeconomic factors. We share the widespread belief that elected officials should have access to the highest quality information when crafting energy and climate policy decisions that must balance multiple concerns. From this perspective, NCA5 is a missed opportunity. What could have been a valuable contribution to informed tradeoffs instead became a misleading advocacy document that corrupts the policymaking process.~~

The National Academies of Science, Engineering and Medicine (NASEM) undertook a detailed review of the draft NCA5 (NASEM 2023). While they raised some of the same concerns that we have articulated herein, their review is superficial overall and appears to be written by authors who share many of the biases of the NCA5 team. There is an inordinate focus on social and policy issues (e.g., every chapter is assessed under the heading "Comments on Equity and Justice"), rather than on the underlying science. In our assessment NASEM failed to apply the serious rigor one would expect. A few extracted comments from it will illustrate. Note that NASEM review comments are included here in blue font for reference.

89 REFERENCES

- Aven, Terje (2017) "Improving Risk Characterisations in Practical Situations by Highlighting Knowledge Aspects, with Applications to Risk Matrices," *Reliability Engineering & System Safety* 167 (November 2017): 42–48 [[HYPERLINK](https://www.sciencedirect.com/science/article/pii/S0951832016306950) "https://www.sciencedirect.com/science/article/pii/S0951832016306950"]
- Climate Working Group (2025) Impacts of Carbon Dioxide Emissions on the U.S. Climate. Washington DC: Department of Energy, May 27, 2025.
- Dellawalla, Colette, Victor Ambrose, Carl Bergstrom *et al.* (2025) "Trump's new 'gold standard' rule will destroy American science as we know it." *The Guardian* May 29, 2025 [[HYPERLINK](https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science) "https://www.theguardian.com/commentisfree/2025/may/29/trump-american-science"]
- Diffenbaugh, N.S., D. Singh, and J.S. Mankin, 2018: Unprecedented climate events: Historical changes, aspirational targets, and national commitments. *Science Advances*, 4 (2), 3354. <https://doi.org/10.1126/sciadv.aao3354>
- Handler, Philip (1980) Public Doubts About Science. *Science* 208(4448) p. 1093 [[HYPERLINK](https://www.science.org/doi/10.1126/science.208.4448.1093) "https://www.science.org/doi/10.1126/science.208.4448.1093"]
- Kirchmeier-Young, M.C. and X. Zhang, 2020: Human influence has intensified extreme precipitation in North America. *Proceedings of the National Academy of Sciences of the United States of America*, 117 (24), 13308-13313. <https://doi.org/10.1073/pnas.1921628117>
- Knutson, Thomas and Fanrong Zeng (2018) "Model Assessment of Observed Precipitation Trends over Land Regions: Detectable Human Influences and Possible Low Bias in Model Trends" *Journal of Climate* 31(12) [[HYPERLINK](https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml) "https://journals.ametsoc.org/view/journals/clim/31/12/jcli-d-17-0672.1.xml"]
- Koonin, Steven (2024) *Unsettled: What Climate Science Tells Us, What It Doesn't, and Why It Matters*. ---: ---
- McKittrick, R., and J.R. Christy (2019). Assessing changes in US regional precipitation on multiple time scales. *Journal of Hydrology*, 578, 124074. [[HYPERLINK](https://doi.org/10.1016/j.jhydrol.2019.124074) "https://doi.org/10.1016/j.jhydrol.2019.124074"]
- [McKittrick, R., and J.R. Christy \(2025\). "Data and Code for DoE Report 2025". Mendeley Data, V1, doi: 10.17632/8n9ks93vn7.1](https://doi.org/10.17632/8n9ks93vn7.1)
- National Academies of Sciences, Engineering, and Medicine. 2023. *Review of the Draft Fifth National Climate Assessment*. Washington, DC: The National Academies Press. [[HYPERLINK](https://doi.org/10.17226/26757) "https://doi.org/10.17226/26757"]
- NCA4. (2017). *Climate science special report: Fourth National Climate Assessment, Volume I* (D. J. Wuebbles, D. W. Fahey, and K. A. Hibbard, Eds.). U.S. Global Change Research Program. [[HYPERLINK](https://doi.org/10.7930/J0J964J6) "https://doi.org/10.7930/J0J964J6"]
- NCA5. (2023). *Fifth National Climate Assessment* (A. R. Crimmins et al., Eds.). U.S. Global Change Research Program. [[HYPERLINK](https://doi.org/10.7930/NCA5.2023.CH1) "https://doi.org/10.7930/NCA5.2023.CH1"]
- Pielke Jr., R. (2024). Scientific integrity and U.S. 'billion dollar disasters'. *npj Natural Hazards*, 1, Article 12. [[HYPERLINK](https://www.nature.com/articles/s44304-024-00011-0) "https://www.nature.com/articles/s44304-024-00011-0"]
- Pielke Jr., R. (2025, May 8). RIP NOAA's billion dollar disasters. *The Honest Broker* [Substack]. [[HYPERLINK](https://rogerpielkejr.substack.com/p/rip-noaas-billion-dollar-disasters) "https://rogerpielkejr.substack.com/p/rip-noaas-billion-dollar-disasters"]
- Schlund, Manuel, Axel Lauer, Pierre Gentine, Steven C. Sherwood, and Veronika Eyring (2020) Emergent constraints on equilibrium climate sensitivity in CMIP5: do they hold for CMIP6? *Earth System Dynamics* 11 1233-1258 [[HYPERLINK](https://doi.org/10.5194/esd-11-1233-2020) "https://doi.org/10.5194/esd-11-1233-2020"]

APPENDICES

APPENDIX 1: Charge to the review

| **APPENDIX 2: statutory requirements for NCA5**

APPENDIX 32: Analysis of U.S. Reproducibility of NCA5 claim of Long-term Precipitation Record extreme precipitation trends

DELETE APPENDIX 3. WE SHOULD NOT BE PRESENTING ORIGINAL ANALYSES IN THIS REPORT
[I'm not sure we need both the tables and multipanel figures here. Is anyone really going to
look at the tables? Perhaps they can be eliminated and just keep the figures?]

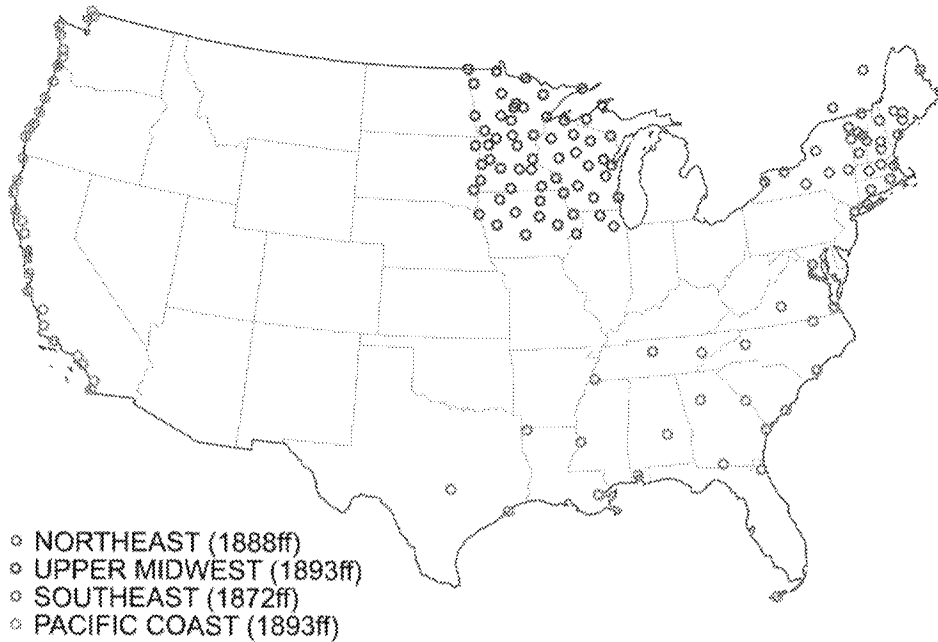


Figure A1: Stations used in the following analyses.

Note: All data are available at Christy (2025). Methods as described in McKittrick and Christy (2019).
code available at McKittrick and Christy (2025).

Figure: Stations used in the following analyses.

Table codes: (-) neg insignificant, -- neg significant, (+) pos insignificant, ++ pos significant.

Column 1: Measure

Column 2: Number of stations in that region

Column 3: Count of stations exhibiting a significant positive trend

Column 3: Count of stations exhibiting a significant negative trend

Column 5: Characteristic of region-wide trend

|

PACIFIC COAST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	9	--
Variability	29	1	0	(+)
Annual max	29	2	1	(+)
Number of 99 th pct exceedances	29	1	0	(-)

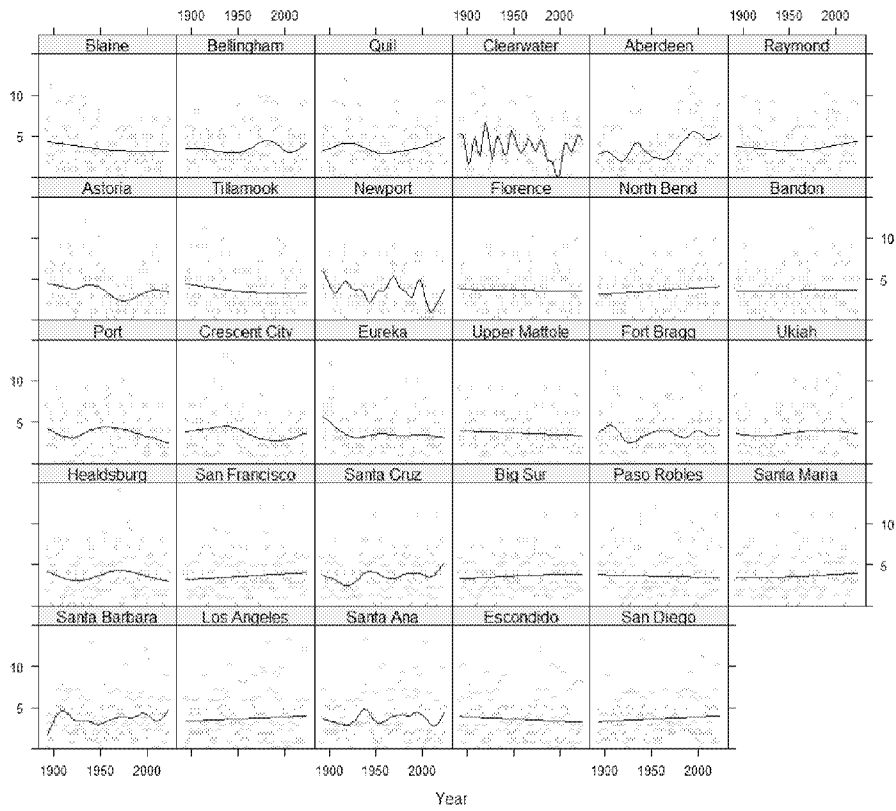
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	29	0	1	(-)
2-day average	29	0	1	(-)
Avg on non-zero days	29	0	4	(-)
Variability	29	2	3	(-)
Annual max	29	6	3	(-)
Number of 99 th pct exceedances	29	2	1	(-)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	29	0	0	(-)
2-day average	29	0	0	(-)
Avg on non-zero days	29	0	1	(-)
Variability	29	0	0	(-)
Annual max	29	2	1	(-)
Number of 99 th pct exceedances	29	0	0	(+)

Annual No. 99th Percentile Exceedances PC 1893-2024



SOUTHEAST

Since 1873:

	No. stns	+ trends	- trends	region
1-day average	24	1	1	(+)
2-day average	24	1	1	(+)
Avg on non-zero days	24	7	2	(+)
Variability	24	1	0	(+)
Annual max	24	2	0	(+)
Number of 99 th pct exceedances	24	5	0	(+)

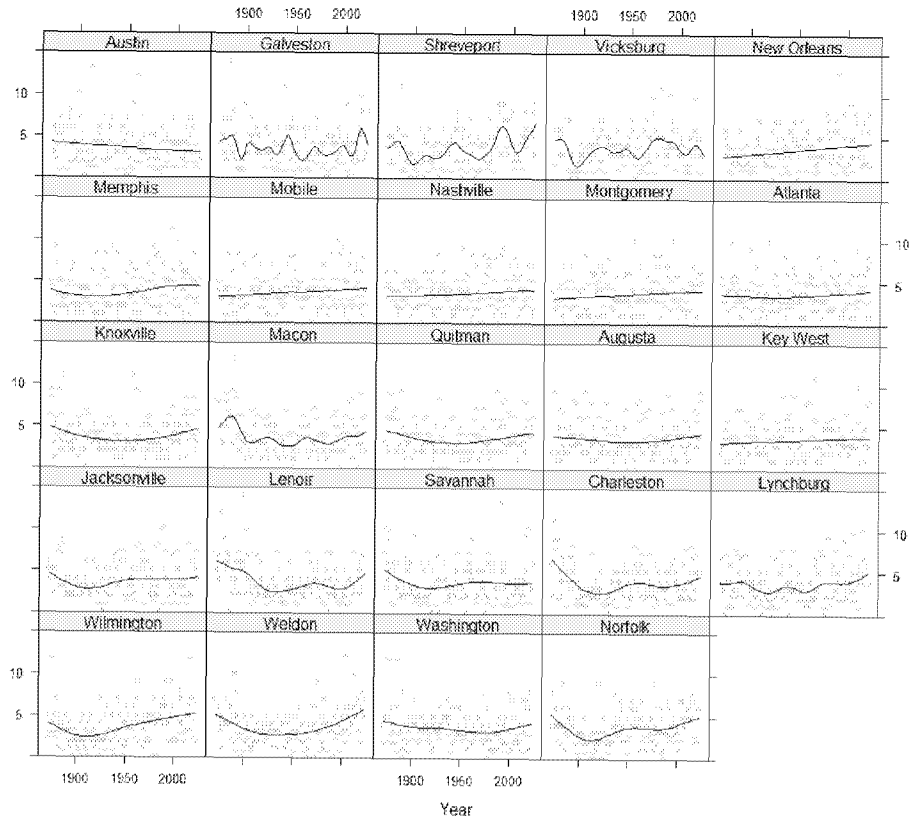
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	++
2-day average	24	5	0	++
Avg on non-zero days	24	5	1	++
Variability	24	6	0	++
Annual max	24	4	0	++
Number of 99 th pct exceedances	24	4	0	(+)

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	24	5	0	(+)
2-day average	24	5	0	(+)
Avg on non-zero days	24	5	1	(+)
Variability	24	3	0	(+)
Annual max	24	4	0	(+)
Number of 99 th pct exceedances	24	4	0	(+)

Annual No. 99th Percentile Exceedances SE 1873-2024



MIDWEST

Since 1893:

	No. stns	+ trends	- trends	region
1-day average	61	23	0	++
2-day average	61	23	0	++
Avg on non-zero days	61	2	12	(+)
Variability	61	12	0	++
Annual max	61	9	0	(+)
Number of 99 th pct exceedances	61	10	0	(+)

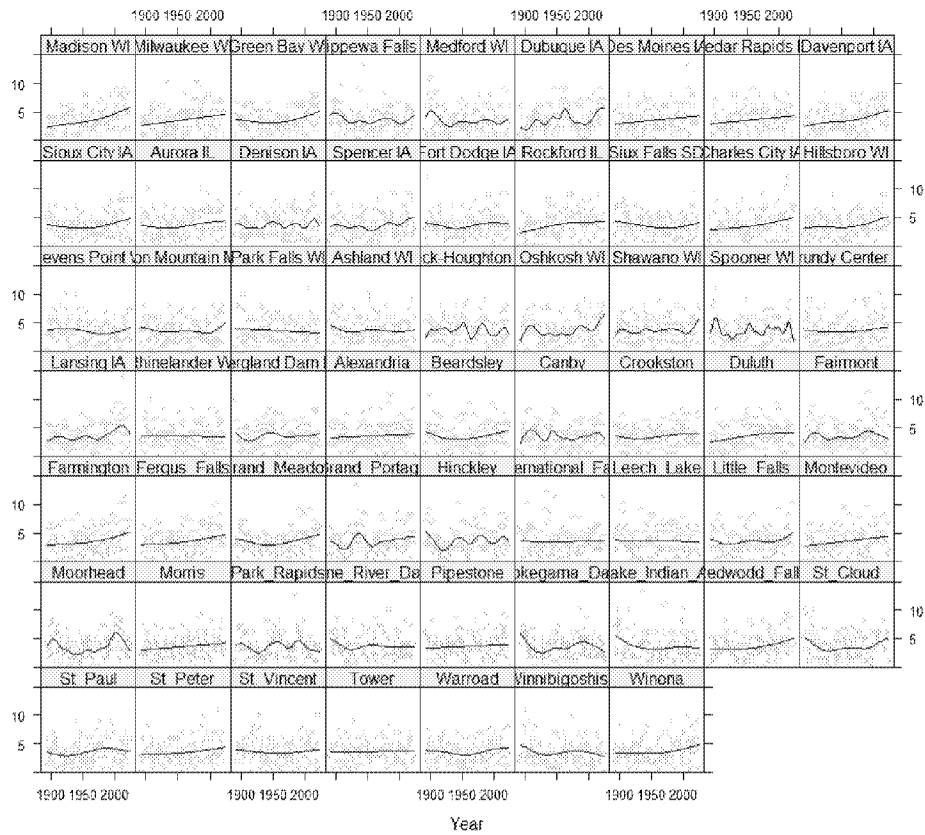
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	61	28	2	++
2-day average	61	28	2	++
Avg on non-zero days	61	11	1	++
Variability	61	16	0	(+)
Annual max	61	8	0	(+)
Number of 99 th pct exceedances	61	19	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	61	6	1	(+)
2-day average	61	6	1	(+)
Avg on non-zero days	61	8	2	(+)
Variability	61	5	1	(+)
Annual max	61	0	1	(+)
Number of 99 th pct exceedances	61	5	3	(-)

Annual No. 99th Percentile Exceedances MW 1893-2024



NORTHEAST

Since 1888:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	(+)

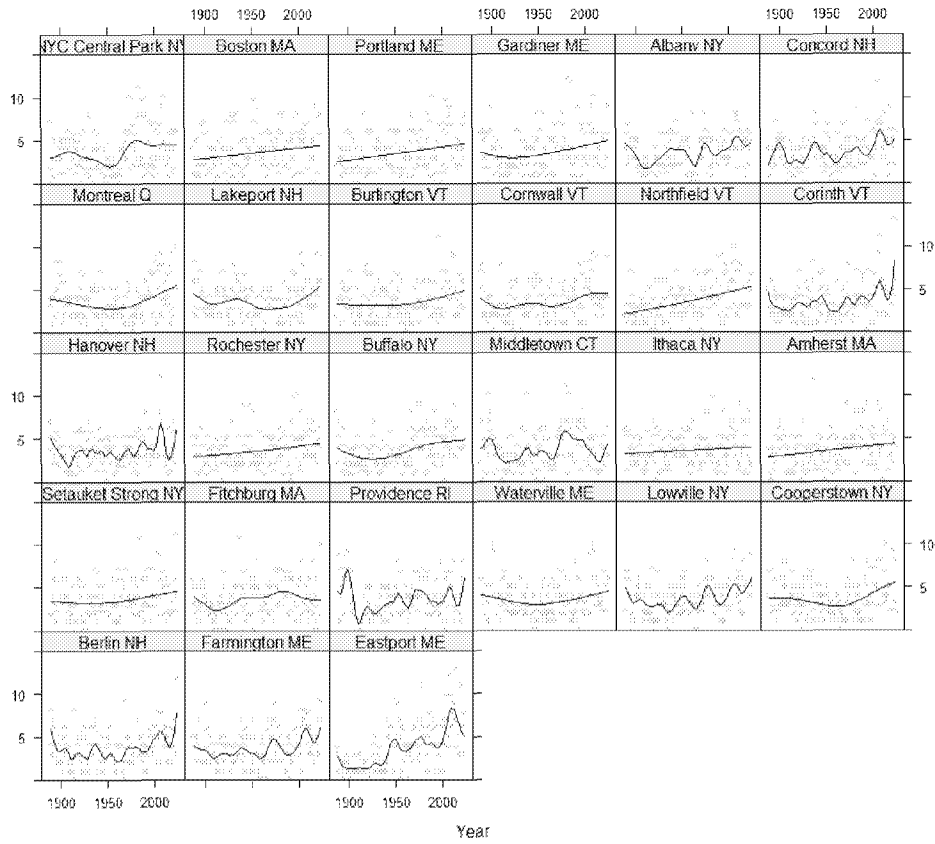
Since 1950:

	No. stns	+ trends	- trends	region
1-day average	27	12	0	++
2-day average	27	12	0	++
Avg on non-zero days	27	7	1	(+)
Variability	27	4	0	(+)
Annual max	27	3	0	(-)
Number of 99 th pct exceedances	27	5	0	++

Since 1980:

	No. stns	+ trends	- trends	region
1-day average	27	10	1	++
2-day average	27	10	1	++
Avg on non-zero days	27	6	0	(+)
Variability	27	2	0	(+)
Annual max	27	1	0	(+)
Number of 99 th pct exceedances	27	1	1	++

Annual No. 99th Percentile Exceedances NE 1888-2024



ABOUT THE AUTHORS

[Insert updated bios]



Impacts of Carbon Dioxide Emissions on the U.S. Climate

Climate Working Group
United States Department of Energy
July 15, 2025

Impacts of Carbon Dioxide Emissions on the U.S. Climate

Report to U.S. Energy Secretary Christopher Wright

July 15, 2025

Climate Working Group:

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SECRETARY'S FOREWORD

Energy, Integrity, and the Power of Human Potential

Over my lifetime, I've had the privilege of working as an energy entrepreneur across a range of fields—nuclear, geothermal, natural gas, and more—and I now serve as Secretary of Energy under President Donald Trump. But above all, I'm a physical scientist who sees modern energy as nothing short of miraculous. It powers every aspect of modern life, drives every industry, and has made America an energy powerhouse with the ability to fuel global progress.

The rise of human flourishing over the past two centuries is a story worth celebrating. Yet we are told—relentlessly—that the very energy systems that enabled this progress now pose an existential threat. Hydrocarbon-based fuels, the argument goes, must be rapidly abandoned or else we risk planetary ruin.

That view demands scrutiny. That's why I commissioned this report: to encourage a more thoughtful and science-based conversation about climate change and energy. With my technical background, I've reviewed reports from the Intergovernmental Panel on Climate Change, the U.S. government's assessments, and the academic literature. I've also engaged with many climate scientists, including the authors of this report.

What I've found is that media coverage often distorts the science. Many people—even well-meaning ones—walk away with a view of climate change that is exaggerated or incomplete. To provide clarity, I asked a diverse team of independent experts to summarize the current state of climate science, with a focus on how it relates to the United States.

I didn't select these authors because we always agree—far from it. In fact, they may not always agree with each other. But I chose them for their rigor, honesty, and willingness to elevate the debate. I exerted no control over their conclusions. What you'll read are their words, drawn from the best available data and scientific assessments.

I've reviewed the report carefully and challenged its findings. I believe it faithfully represents the state of climate science today. Still, many readers may be surprised by its conclusions—which differ in important ways from the mainstream narrative. That's a sign of how far the public conversation has drifted from the science itself.

To correct course, we need open, respectful, and informed debate. That's why I'm inviting public comment on this report. Honest scrutiny and scientific transparency should be at the heart of our policymaking.

Climate change is real, and it deserves attention. But it is not the greatest threat facing humanity. That distinction belongs to global energy poverty. As someone who values data, I know that improving the human condition depends on expanding access to reliable, affordable energy. Climate change is a challenge—not a catastrophe. But misguided policies based on fear rather than facts could truly endanger human well-being.

We stand at the threshold of a new era of energy leadership. If we empower innovation rather than restrain it, America can lead the world in providing cleaner, more abundant energy—lifting billions out of poverty, strengthening our economy, and improving our environment along the way.

EXECUTIVE SUMMARY

This report reviews scientific certainties and uncertainties in how anthropogenic carbon dioxide (CO₂) emissions have affected, or will affect, the Nation's climate, extreme weather events, and selected metrics of societal well-being. Those emissions are increasing the concentration of CO₂ in the atmosphere through a complex and variable carbon cycle, where some portion of the additional CO₂ persists in the atmosphere for centuries.

Elevated concentrations of CO₂ directly enhance plant growth, globally “greening” the planet and increasing agricultural productivity. They also make the oceans less alkaline (lower the pH) by an amount within the range of natural variability. That is possibly detrimental to coral reefs, although the recent rebound of the Great Barrier Reef suggests otherwise.

Carbon dioxide also acts as a greenhouse gas, exerting a warming influence on climate and weather. Scenarios of future CO₂ emissions have tended to overestimate observed levels.

The world's several dozen detailed climate models offer little guidance on how the climate responds to elevated CO₂, with the average surface warming under a doubling of the CO₂ concentration ranging from 1.8°C to 5.7°C, a larger range than data driven estimates that suggest a response in the range 1.8°C to 2.7°C.

Detailed climate models generally run “hot” in their description of the climate of the past few decades - too much warming at the surface and too much amplification of warming in the lower- and mid-troposphere. They also produce too much stratospheric cooling, too much snow loss, and too much warming in the U.S. Corn Belt. The combination of overly sensitive models and extreme scenarios for future emissions has exaggerated projections of future warming.

Most extreme weather events do not show long-term trends. Claims of increased frequency or intensity of hurricanes, tornadoes, floods, and droughts are not supported by historical data. Additionally, forest management practices are often overlooked in assessing wildfire activity. Global sea level has risen approximately 8 inches since 1900, but there are significant regional variations in tide gauge data driven primarily by local land subsidence; U.S. tide gauge measurements in aggregate show no obvious acceleration in sea level rise beyond the historical average rate.

The attribution of particular climate changes or extreme weather events to human CO₂ emissions is challenged by natural climate variability, data limitations, and inherent model deficiencies. Moreover, solar activity's contribution to the late 20th century warming might be underestimated.

Both models and experience suggest that CO₂-induced warming might be less damaging economically than commonly believed, and excessively aggressive mitigation policies could prove more detrimental than beneficial. Social Cost of Carbon estimates, which attempt to quantify the economic damage of CO₂ emissions, are highly sensitive to their underlying assumptions and so provide limited independent information.

The report supports a more nuanced and evidence-based approach for informing climate policy. The risks and benefits of a climate changing under both natural and human influences must be weighed against the costs, efficacy, and collateral impacts of any “climate action”, considering the nation's need for reliable and affordable energy with minimal local pollution. Beyond continuing precise, un-interrupted observations of the global climate system, it will be important to make realistic assumptions about future emissions, re-evaluate climate models to address biases and uncertainties, and clearly acknowledge the limitations of extreme event attribution studies. An approach that acknowledges both the potential risks and benefits of CO₂, rather than relying on flawed models and extreme scenarios, is essential for informed and effective decision-making.

PREFACE

This document originated in late March 2025 when Secretary Wright assembled an independent group to write a report on issues in climate science relevant for energy policymaking, with particular focus on the question of whether carbon dioxide emissions endanger the U.S. public. We agreed to undertake the work on the condition that there would be no editorial oversight by the Secretary, the Department of Energy, or any other government personnel. This condition has been honored throughout the process and the writing team has worked with full independence.

The group began working in early April with a deadline of May 28. The short timeline and the technical nature of the material meant that we could not comprehensively review all topics. Rather, we chose to focus on topics that are treated by a serious, established academic literature; that are relevant to our charge; that are downplayed in, or absent from, recent assessment reports; and that are within our competence.

While the report is intended to be accessible to non-experts, we have omitted some introductory or explanatory material that can easily be accessed elsewhere. Nor have we attempted to survey entire literatures related to the topics covered. We have focused as much as possible on literature published since 2020 and referenced previous IPCC and NCA assessment reports. We have also used data through 2024 where possible.

The writing team is grateful to Secretary Wright for the opportunity to prepare this report and for his support of independent scientific assessment and open scientific debate.

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Judith Curry, Ph.D.

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Ross McKittrick, Ph.D.

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**PART I: DIRECT HUMAN INFLUENCE ON ECOSYSTEMS AND THE
CLIMATE**

1 CARBON DIOXIDE AS A POLLUTANT

Chapter summary:

Carbon dioxide (CO₂) differs in many ways from the so-called Criteria Air Pollutants. It does not affect local air quality and has no human toxicological implications at ambient levels. It is an issue of concern because of its potential effects on the global climate, a complex issue that occupies much of this report.

The Clean Air Act of 1970 defined six so-called Criteria Air Contaminants subject to regulation (EPA): particulate matter, ground-level ozone, sulfur dioxide, nitrogen dioxide, lead, and carbon monoxide. In 2007, the Supreme Court ruled that greenhouse gases (CO₂ among them) were also “pollutants” subject to regulation under Clean Air Act (*Mass. v. EPA*, 2007). While the definition of “pollutant” is ultimately a legal matter, there are important scientific distinctions between CO₂ and the Criteria Air Contaminants. The latter are subject to regulatory control because they cause local problems depending on concentrations that include nuisances (odor, visibility), damage to plants, and, at high enough exposure levels, toxicological effects in humans. In contrast, CO₂ is odorless, does not affect visibility and has no toxicological effects at ambient levels. It is a naturally occurring part of the atmosphere and a key component of human and plant respiration. CO₂ is essential for plant photosynthesis and higher levels are beneficial for vegetation. In these aspects, CO₂ is similar to water vapor.

Ambient outdoor air today contains about 430 parts per million (ppm) CO₂, increasing at about 2 ppm per year. The U.S. Occupational Safety and Health Administration issues guidelines for indoor workplaces in which elevated CO₂ might be encountered, such as where dry ice is used. The Permissible Exposure Limit is 5,000 ppm over 8 hours (OSHA, 2024). Allen *et al.* (2015) reported evidence of diminished performance on some cognitive tasks among workers in office cubicles when exposed to CO₂ levels above 1,000-1,500 ppm. These levels are far larger than any plausible ambient outdoor value through the end of the 22nd century.

The growing amount of CO₂ in the atmosphere directly influences the earth system by promoting plant growth (global greening), thereby enhancing agricultural yields, and by neutralizing ocean alkalinity. But the primary concern about CO₂ is its role as a greenhouse gas (GHG) that alters the earth’s energy balance. How the climate will respond to that influence is a complex question that will occupy much of this report.

References

- Allen, J., Macnaughton, P., Satish, U., *et al.* (2015). Associations of cognitive function scores with carbon dioxide, ventilation, and volatile organic compound exposures in office workers: A controlled exposure study of green and conventional office environments. *Environmental Health Perspectives*. 124. <https://doi.org/10.1289/ehp.1510037>
- Massachusetts v. Environmental Protection Agency, 549 U.S. 497 (2007). [[HYPERLINK "https://www.oyez.org/cases/2006/05-1120"](https://www.oyez.org/cases/2006/05-1120)]
- U.S. Environmental Protection Agency. (n.d.). Criteria air pollutants. [[HYPERLINK "https://www.epa.gov/criteria-air-pollutants"](https://www.epa.gov/criteria-air-pollutants)]
- U.S. Occupational Safety and Health Administration. (2024). OSHA occupational chemical database: Carbon dioxide. [[HYPERLINK "https://www.osha.gov/chemicaldata/183"](https://www.osha.gov/chemicaldata/183)]

2 DIRECT IMPACTS OF CO₂ ON THE ENVIRONMENT

Chapter summary:

CO₂ enhances photosynthesis and improves plant water use efficiency, thereby promoting plant growth. Global greening due to increased CO₂ levels in the atmosphere is well-established on all continents.

CO₂ absorption in sea water makes the oceans less alkaline. The recent decline in pH is within the range of natural variability on millennial time scales. Most ocean life evolved when the oceans were mildly acidic. Decreasing pH might adversely affect corals, although the Australian Great Barrier Reef has shown considerable growth in recent years.

2.1 CO₂ and global greening

The growing CO₂ concentration in the atmosphere has the important positive effect of promoting plant growth by enhancing photosynthesis and improving water use efficiency. That is evident in the “global greening” phenomenon discussed below, as well as in the improving agricultural yields discussed in Chapter 10.

2.1.1 Measurement of global greening

“Greening” refers to an increase in the fraction of the Earth’s surface covered by plants. It can be quantified by the “Leaf Area Index” (LAI) measured by satellite. Many studies over the past decade have confirmed a global greening pattern (increase in LAI) attributable to rising CO₂ levels. Zhu *et al.* (2016) was one of the first studies to report that global greening was detectable using satellite sensors. From 1982 to 2011 they detected greening over 25-50 percent of the Earth versus “browning” over only four percent and attributed 70 percent of the greening to rising CO₂ levels (see Figure 2.1).

Zheng *et al.* (2017) confirmed the pattern, noting that greening over thirty years had added 8 percent to global leaf area and that greening was mitigating warming. Greening has been observed globally but Chen *et al.* (2019) noted that China and India were exploiting it through land management changes. Thus, while China accounts for only 6.6 percent of global vegetated area it accounts for 25 percent of global net increase in LAI. Piao *et al.* (2020) noted that greening was even observable in the Arctic.

While plant models predict increased photosynthesis in response to rising CO₂, Haverd *et al.* (2020) reported a CO₂ fertilization rate nearly double model predictions. That is, CO₂ fertilization had driven an increase in observed global photosynthesis by 30 percent since 1900, versus 17 percent predicted by plant models. This indicates that global models of the socioeconomic impacts of rising CO₂ have likely understated the benefits to crops and agriculture. The connection between CO₂ fertilization and agriculture will be discussed in Chapter 9.

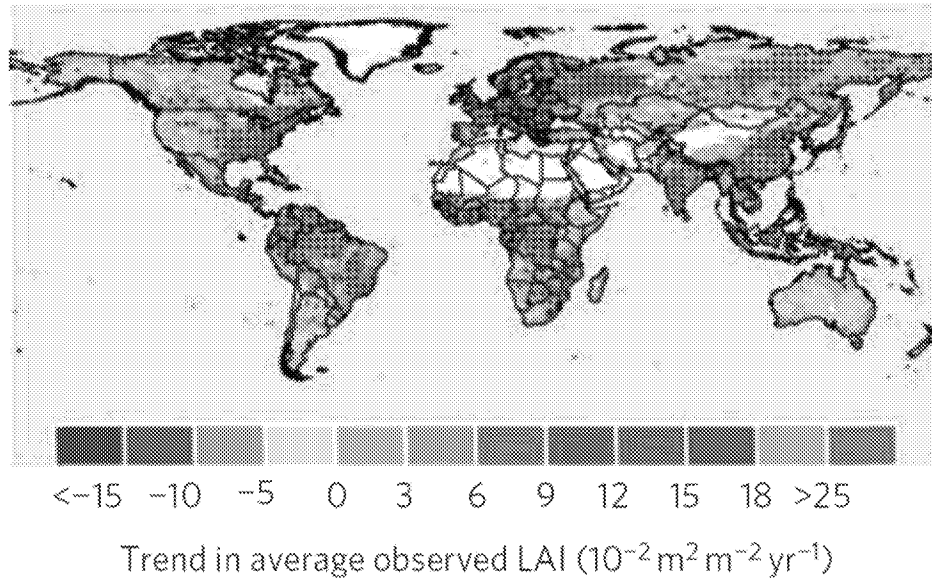


Figure 2.1: Trends in average Leaf Area Index (LAI). Source: Zhu *et al.* 2016 Figure 3.

Finally, Chen *et al.* (2024) surveyed claims that greening had slowed since 2000 due to drought stress. They found instead that faulty satellite sensors were the cause and that the corrected data showed accelerated greening over 55 percent of the globe while browning was accelerating over only 7 percent. In other words, the greening trend continued with no evidence of slowdown, and CO_2 fertilization remained the dominant driver

2.1.2 Photosynthesis and CO_2 levels

Plants build biomass through *photosynthesis*, a process that converts carbon dioxide, water, and light into sugar. The plant enzyme responsible for photosynthesis is Ribulose-1,5-bisphosphate-carboxylase/oxygenase or “Rubisco”. Photosynthesis is initiated when CO_2 is available at the surface of the Rubisco enzyme where it is converted to a molecule with 3 carbon atoms and thereafter incorporated into plant mass. This is referred to as the “C3” process.

Rubisco is estimated to have evolved about 3 billion years ago. Over geological time the Earth’s atmospheric CO_2 levels were usually many times higher than they are today, as shown in Figure 2.2.

About 400 million years ago CO_2 levels were an estimated 2,000-4,000 ppm and were at or above 1,000 ppm for much of the interval from 200 to 50 million years ago (Berner 2006, Judd *et al.* 2024). Over the past 35 million years the level of atmospheric CO_2 has been steadily declining, falling to as low as 170 ppm during glaciations (Gerhart and Ward 2010).

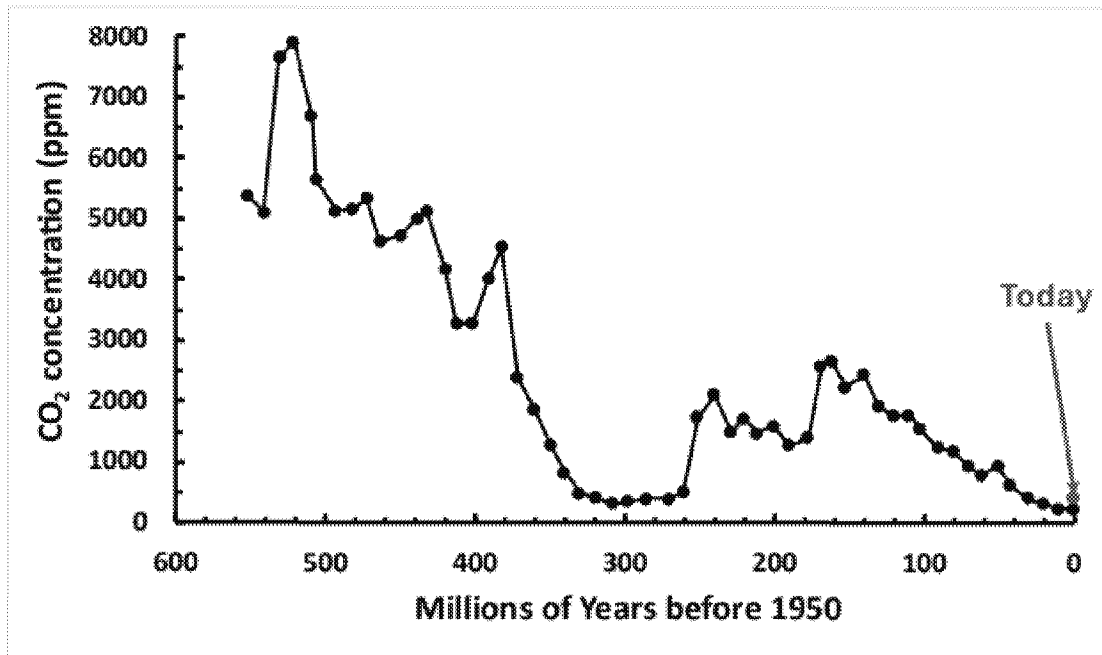


Figure 2.2. Ambient CO₂ levels over the past 550 million years. Today's concentration of 430 ppm is also shown. Source: (Berner 2006)

In response to low-CO₂ conditions some plants evolved another photosynthetic pathway called C₄, in which CO₂ is concentrated in the vicinity of Rubisco, allowing for the C₃ process to function more efficiently. For agricultural purposes the plant categories are:

- C₃: rice, wheat, soybeans and most other crops
- C₄: maize (corn), sugar cane, millet, sorghum

Had atmospheric CO₂ levels continued declining, plant growth would have declined and eventually ceased. Below 180 ppm, the growth rates of many C₃ species are reduced 40-60 percent relative to 350 ppm (Gerhart and Ward 2010) and growth has stopped altogether under experimental conditions of 60—140 ppm CO₂. Some C₄ plants are still able to grow at levels even as low as 10 ppm, albeit very slowly (Gerhart and Ward 2010).

Current CO₂ levels are about 430 ppm, up from 280 ppm in the early 1800s. The positive response of plants to extra CO₂ is illustrated in Figure 2.3, reproduced from Gerhart and Ward (2010). It shows the growth effect of CO₂ on Velvetleaf (*Abutilon theophrasti*) seedlings over 14 days under controlled conditions where only the CO₂ exposure is varied. The gains induced by increasing CO₂ from 150 ppm to 350 ppm continue under a further doubling to 700 ppm.

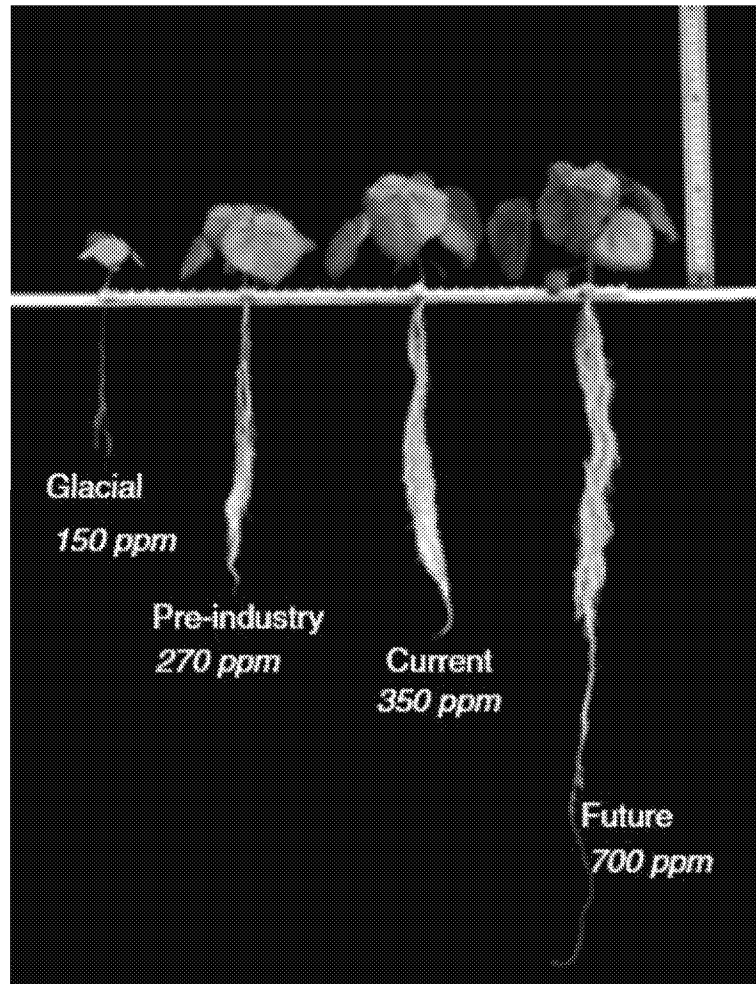


Figure 2.3: growth of *Abutilon theophrasti* after 14 days under identical conditions but for the indicated variations in CO₂ levels. Source: Gerhart and Ward (2010). Note “Current” corresponds to 1988 in image.

Over the past 60+ years there have been thousands of studies on the response of plants to rising CO₂ levels. The overwhelming theme is that plants, especially C3 plants, benefit from extra CO₂. There are two mechanisms by which CO₂ confers a growth benefit:

- Enhanced photosynthesis via the metabolic pathways described above.
- Increased water use efficiency. This arises because plants draw in CO₂ by opening the stomata (pores) on the leaf surface. When CO₂ is scarce the stomata must be kept wide open for long periods, allowing water to evaporate. Under enriched CO₂ conditions the stomata remain closed for longer periods, thus helping the plant retain water longer, and so increasing water use efficiency.

Specific effects of climate change on U.S. agriculture will be reviewed in Chapter 9.

2.1.3 Rising CO₂ and crop water use efficiency

Derying *et al.* (2016) surveyed evidence on crop water productivity (CWP), the yield per unit of water used, drawing attention to the potential for CO₂ both to enhance photosynthesis and to reduce leaf-level transpiration (water loss during leaf respiration). They surveyed all available FACE data (Free Air CO₂ Enrichment—see Chapter 9) on crop yield changes for maize (corn), wheat, rice, and soybean and combined

it with crop model data simulating yield responses as of 2080 under the extreme RCP8.5 emissions scenario in four growing regions (Tropics, Arid, Temperate and Cold) each of which were split into rainfed and irrigated sub-regions. They reported that models without CO₂ fertilization predicted CWP losses in every region, but those were more than offset by CO₂ fertilization so that all regions showed a net CWP gain. Deryng *et al.* (2016) also reported that negative impacts of warming on wheat and soybean yields were fully offset by CWP gains and mitigated by up to 90 percent for rice and 60 percent for maize.

Similarly, Cheng *et al.* (2017) noted that increased global plant growth from 1982 to 2011 due to rising CO₂ uptake was accompanied by such large gains in CWP that global water use by plants had not increased, despite the extra biomass.

Deryng *et al.* (2016) assumed that climate change would “exacerbate water scarcity”. Yet while models do predict that drylands will expand under climate warming, current data show the opposite: greening is happening even in arid areas. Zhang *et al.* (2024) report that due to increased CO₂ levels “increasing aridity in drylands won’t lead to a general loss of vegetation productivity”; at most only 4 percent of currently arid areas will see increased desertification.

2.1.4 CO₂ fertilization benefits in IPCC Reports

The IPCC has only minimally discussed global greening and CO₂ fertilization of agricultural crops. The topic is briefly acknowledged in a few places in the body of the IPCC 6th and earlier Assessment Reports but is omitted in all Summary documents. Section 2.3.4.3.3 of the AR6 Working Group I report, entitled “global greening and browning,” points out that the IPCC Special Report on Climate Change and Land had concluded with *high confidence* that greening had increased globally over the past 2-3 decades. It then discusses that there are variations in the greening trend among data sets, concluding that while they have *high confidence* greening has occurred, they have *low confidence* in the magnitude of the trend. There are also brief mentions of CO₂ fertilization effects and improvements in water use efficiency in a few other chapters in the AR6 Working Groups I and II Reports.

Overall, however, the Policymaker Summaries, Technical Summaries, and Synthesis Reports do not discuss the topic.

2.2 The Alkaline Oceans

2.2.1 Changing pH

A neutral aqueous solution has a pH of 7.0, while one with pH greater than 7.0 is alkaline (also termed basic) and with pH less than 7.0 is acidic. The modern-day global average pH of sea water is estimated to be 8.04 (Copernicus Marine Service 2025), down from an estimated value of 8.2 in pre-Industrial times (Gattuso and Hansson, 2011). As CO₂ concentrations in the atmosphere increased, the oceans absorbed more, which decreases their pH. Depending upon the oceans’ buffering capacity, they are expected to become somewhat less alkaline over time, consistent with the observed decrease in pH.

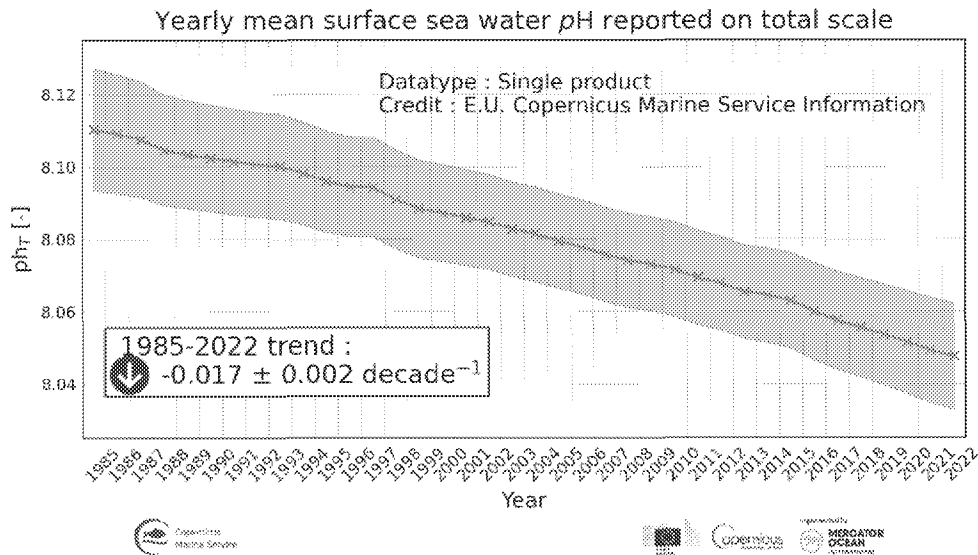


Figure 2.4: Ocean pH 1985 – 2022. Source: Copernicus Marine Service 2025

While this process is often called “ocean acidification”, it is a misnomer because the oceans are not expected to become acidic; “ocean neutralization” would be more accurate. Even if the water were to turn acidic, it is believed that life in the oceans evolved when the oceans were mildly acidic with pH 6.5 to 7.0 (Krissansen-Totton *et al.*, 2018). On the time scale of thousands of years, boron isotope proxy measurements show that ocean pH was around 7.4 or 7.5 during the last glaciation (up to about 20,000 years ago) increasing to present-day values as the world warmed during deglaciation (Rae *et al.*, 2018). Thus, ocean biota appear to be resilient to natural long-term changes in ocean pH since marine organisms were exposed to wide ranges in pH.

2.2.2 Coral reef changes

There are concerns that a decreasing pH of sea water will reduce the calcification rate of coral reefs. But coral reefs already endure large swings in pH, partly due to daily photosynthetic activity in the reef; measured pH values range from 9.4 during the day to 7.5 at night (Revelle and Fairbridge, 1957). De’ath *et al.* (2009) reported that a portion of Australia’s Great Barrier Reef (GBR, the world’s largest coral reef ecosystem) had experienced a 14 percent decline in calcification since 1990. This was tentatively attributed to increasing water temperature and decreasing pH. But Ridd *et al.* (2013) showed that report to have resulted from a biased data analysis that, when corrected, showed no change in calcification rates. Nevertheless, the alarm produced by the original paper has persisted as evidenced by the large number of published citations (541) to the original study compared to only 11 citations to the correction (as of 30 April 2025).

The most recent annual summary of GBR conditions from the Australian Institute of Marine Science indicates that coral production has rebounded strongly (AIMS, 2023). Figure 2.5 shows the results of the AIMS surveys of hard coral cover, expressed as a percentage of the reef area. Much of the decline in the GBR before 2011 turned out to be due to intense tropical cyclone activity (Beeden *et al.*, 2015) as well as a string of marine heatwaves, agricultural runoff and invasive species (Woods Hole, 2023). Given the reported declines in GBR calcification between 1990 and 2009 and the continued increase in atmospheric CO₂ levels the rebound has surprised some observers.

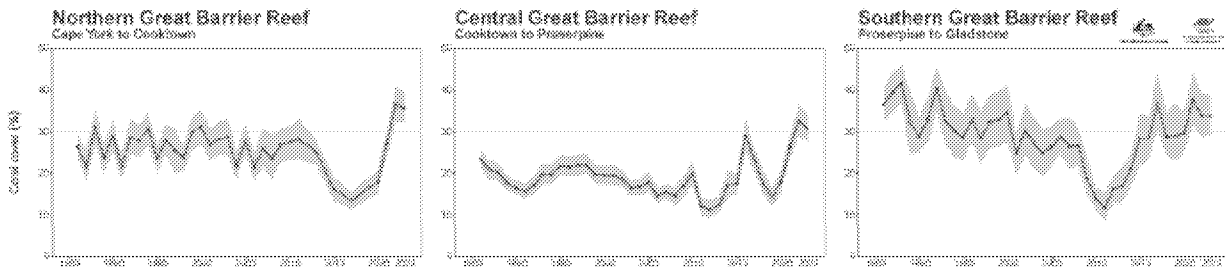


Figure 2.5 Hard coral cover of three regions of the Great Barrier Reef 1985 to 2023. Source: AIMS 2023.

It is being increasingly recognized that publication bias (alarming ocean acidification results preferred by high-impact research publications) exaggerates the reported impacts of declining ocean pH. An ICES Journal of Marine Science Special Issue addressed this problem with an article entitled, *Towards a Broader Perspective on Ocean Acidification Research*. In the Introduction to that Special Issue, H. I. Browman stated, “As is true across all of science, studies that report no effect of ocean acidification are typically more difficult to publish.” (Browman, 2016).

Similarly, a meta-analysis (Clements *et al.*, 2021) of the negative effects of ocean acidification on reef fish behavior found what they called a “decline effect”: initially dramatic conclusions published in prominent journals showing apparently large impacts of acidification tended to be followed up by subsequent studies on larger sample sizes yielding much smaller and typically non-existent effects. They call for their colleagues to improve research practices to counter the “decline effect”:

[The] vast majority of studies with large effect sizes in this field tend to be characterized by low sample sizes, yet are published in high-impact journals and have a disproportionate influence on the field in terms of citations. We contend that ocean acidification has a negligible direct impact on fish behavior, and we advocate for improved approaches to minimize the potential for a decline effect in future avenues of research (Clements *et al.*, 2021).

In summary, ocean life is complex and much of it evolved when the oceans were acidic relative to the present. The ancestors of modern coral first appeared about 245 million ago; as can be seen from Figure 2.2, CO₂ levels for more than 200 million years afterward were many times higher than they are today. Much of the public discussion of the effects of ocean “acidification” on marine biota has been one-sided and exaggerated. There is a known tendency for studies reporting dramatic effects on things like coral cover and fish behavior to get published in high-impact journals and receive widespread press coverage, then subsequent research rebutting those findings receives little attention.

References

- AR6: *Intergovernmental Panel on Climate Change Sixth Assessment Report* (2021) Working Group I Contribution. [[HYPERLINK "http://www.ipcc.ch"](http://www.ipcc.ch)].
- Australian Institute of Marine Science. (2022). Continued coral recovery leads to 36-year highs across two-thirds of the Great Barrier Reef. [[HYPERLINK "https://www.aims.gov.au/sites/default/files/2022-08/AIMS_LTMP_Report_on%20GBR_coral_status_2021_2022_040822F3.pdf"](https://www.aims.gov.au/sites/default/files/2022-08/AIMS_LTMP_Report_on%20GBR_coral_status_2021_2022_040822F3.pdf)]

- Beeden, R., Maynard, J., Puotinen, M., Marshall, P., Dryden, J., Goldberg, J., and Williams, G. (2015). Impacts and recovery from Severe Tropical Cyclone Yasi on the Great Barrier Reef. *PLOS ONE*, 10, e0121272. [HYPERLINK "<https://doi.org/10.1371/journal.pone.0121272>"]
- Berner, R. A. (2006). GEOCARBSULF: A combined model for Phanerozoic atmospheric O₂ and CO₂. *Geochimica et Cosmochimica Acta*, 70, 5653–5664.
- Browman, H. I. (2016). Applying organized scepticism to ocean acidification research. *ICES Journal of Marine Science*, 73(3), 529.1–536. [HYPERLINK "<https://doi.org/10.1093/icesjms/fsw010>"]
- Chen, C., Park, T., Wang, X., Piao, S., Xu, B., Chaturvedi, R. K., and Myneni, R. B. (2019). China and India lead in greening of the world through land-use management. *Nature Sustainability*, 2, 122–129. [HYPERLINK "<https://www.nature.com/articles/s41893-019-0220-7>"]
- Chen, X., Wang, Y., Liu, Y., and Piao, S. (2024). The global greening continues despite increased drought stress since 2000. *Global Ecology and Conservation*, 49, e02791. [HYPERLINK "<https://www.sciencedirect.com/science/article/pii/S2351989423004262>"]
- Cheng, L., Zhang, L., Wang, Y. P., *et al.* (2017). Recent increases in terrestrial carbon uptake at little cost to the water cycle. *Nature Communications*, 8, 110. [HYPERLINK "<https://doi.org/10.1038/s41467-017-00114-5>"]
- Clements, J. C., Sundin, J., Clark, T. D., and Jutfelt, F. (2022). Meta-analysis reveals an extreme “decline effect” in the impacts of ocean acidification on fish behavior. *PLOS Biology*, 20(2), e3001511. [HYPERLINK "<https://doi.org/10.1371/journal.pbio.3001511>"]
- Copernicus Marine Service. (2025). Global ocean acidification – Mean sea water pH time series and trend from multi-observations reprocessing. [HYPERLINK "https://data.marine.copernicus.eu/product/GLOBAL_OMI_HEALTH_carbon_ph_area_averaged/description"]
- De’ath, G., Lough, J., and Fabricius, K. (2009). Declining coral calcification on the Great Barrier Reef. *Science*, 323, 116–119. [HYPERLINK "<https://doi.org/10.1126/science.1165283>"]
- Deryng, D., Conway, D., Ramankutty, N., Price, J., Warren, R., Jones, R., ... and Elliott, J. (2016). Regional disparities in the beneficial effects of rising CO₂ concentrations on crop water productivity. *Nature Climate Change*. [HYPERLINK "<https://doi.org/10.1038/nclimate2995>"]
- Gattuso, J. P., and Hansson, L. (Eds.). (2011). *Ocean acidification: Background and history*. Oxford University Press.
- Gerhart, L. M., and Ward, J. K. (2010). Plant responses to low [CO₂] of the past. *New Phytologist*, 188, 674–695. [HYPERLINK "<https://nph.onlinelibrary.wiley.com/doi/pdf/10.1111/j.1469-8137.2010.03441.x>"]
- Haverd, V., Raupach, M., Briggs, P., *et al.* (2020). Higher than expected CO₂ fertilization inferred from leaf to global observations. *Global Change Biology*, 26, 2390–2402.
- Judd, E. J., Scotese, C. R., Young, S. A., *et al.* (2024). A 485-million-year history of Earth’s surface temperature. *Science*, 385(6715). [HYPERLINK "<https://doi.org/10.1126/science.adk3705>"]
- Krissansen-Totton, J., Arney, G. N., and Catling, D. C. (2018). Constraining the climate and ocean pH of the early Earth with a geological carbon cycle model. *Proceedings of the National Academy of Sciences*, 115(6), 4105–4110. [HYPERLINK "<https://doi.org/10.1073/pnas.1721296115>"]
- Piao, S., Wang, X., Park, T., *et al.* (2020). Characteristics, drivers and feedbacks of global greening. *Nature Reviews Earth and Environment*, 1, 14–27.
- Rae, J. W. B., Burke, A., Robinson, L. F., *et al.* (2018). CO₂ storage and release in the deep Southern Ocean on millennial to centennial timescales. *Nature*, 562, 569–573. [HYPERLINK "<https://doi.org/10.1038/s41586-018-0614-0>"]
- Revelle, R., and Fairbridge, R. W. (1957). Carbonate and carbon dioxide. In J. W. Hedgpeth (Ed.), *Treatise on marine ecology and paleoecology* (Vol. 1). *Geological Society of America*.
- Ridd, P., Silva, E., and Stieglitz, T. (2013). Have coral calcification rates slowed in the last twenty years? *Marine Geology*, 346, 392–399. [HYPERLINK "<https://doi.org/10.1016/j.margeo.2013.09.002>"]

- Woods Hole Oceanographic Institution. (2023). Is the Great Barrier Reef making a comeback? [HYPERLINK "<https://www.whoi.edu/oceanus/feature/is-the-great-barrier-reef-making-a-comeback/>"]
- Zeng, Z., Piao, S. Li, L., *et al.* (2017). Climate mitigation from vegetation biophysical feedbacks during the past three decades. *Nature Climate Change*. <https://doi.org/10.1038/nclimate3299>
- Zhang, Y., Liu, Y., Chen, X., *et al.* (2024). Less than 4% of dryland areas are projected to desertify despite increased aridity under climate change. *Nature Communications Earth and Environment*, 5. [HYPERLINK "<https://www.nature.com/articles/s43247-024-01463-y>"]
- Zhu, Z., Piao, S., Myneni, R. B., *et al.* (2016). Greening of the Earth and its drivers. *Nature Climate Change*, 6, 791–795. [HYPERLINK "<https://www.nature.com/articles/nclimate3004>"]

3 HUMAN INFLUENCES ON THE CLIMATE

Chapter Summary:

The global climate is naturally variable on all time scales. Anthropogenic CO₂ emissions add to that variability by changing the total radiative energy balance in the atmosphere.

The IPCC has downplayed the role of the sun in climate change but there are plausible solar irradiance reconstructions that imply it contributed to recent warming.

Climate projections are based on IPCC emission scenarios that have tended to exceed observed trends. Most academic climate impact studies in recent years are based upon the extreme RCP 8.5 scenario that is now considered implausible; its use as a business-as-usual scenario has been misleading.

Carbon cycle models connect annual emissions to growth in the atmospheric CO₂ stock. While models disagree over the rate of land and ocean CO₂ uptake, all agree that it has been increasing since 1959.

3.1 Components of radiative forcing and their history

3.1.1 Historical radiative forcing

A changing climate has been the norm throughout the Earth's 4.6-billion-year history. The Earth's temperature and weather patterns change naturally over timescales ranging from decades to millions of years. Natural variations in the surface climate originate in two ways. Internal climate fluctuations associated with circulations in the atmosphere and ocean exchange energy, water, and carbon between the atmosphere, oceans, land, and ice. External influences on the climate system include variations in the energy received from the sun and the effects of volcanic eruptions. Human activities influence climate through changing land use and land cover. Humans are also changing the composition of the atmosphere by emissions of CO₂ and other greenhouse gases and by altering the concentration of aerosol particles in the atmosphere.

The earth is warmed by the sunlight it absorbs and is cooled by the heat it radiates to space. Averaged over the Earth's surface, each of these processes involve power flows of about 240 Watts per square meter (W/m²). When they are in balance, there are no net external causes of warming or cooling. Both human and natural influences on the climate alter this balance and so cause the climate to change.

Influences on the Earth's energy balance at the top of the atmosphere are quantified by "radiative forcing", the extent to which they disturb the warming/cooling balance; a positive forcing warms while a negative forcing cools. The IPCC's estimated history of major components of radiative forcing since 1750 is shown in the following two figures from its AR6.

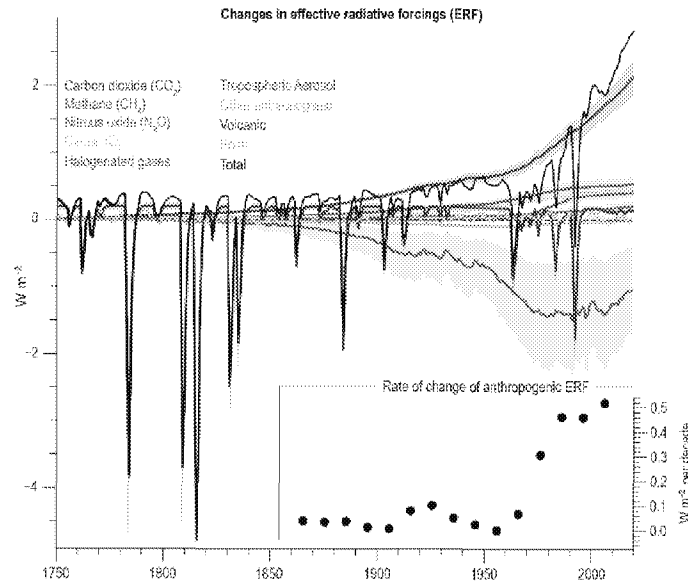


Figure 3.1.1: IPCC estimates of radiative forcing components over time. Shading indicates uncertainty ranges. Source: AR6 WGI Ch2 Fig. 10

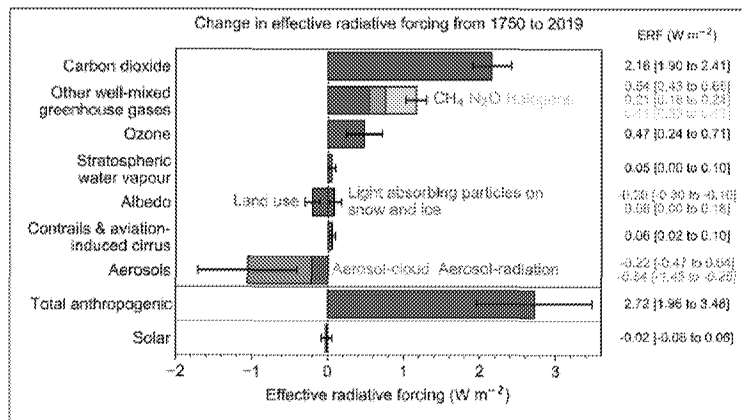


Figure 3.1.2 IPCC estimates of radiative forcing component changes from 1750 to 2019. Source: AR6 WGI Ch 7 Fig. 7-6.

These graphs show that the total radiative forcing is comprised of both natural and anthropogenic components. Carbon dioxide is the largest human influence on the climate and the one most relevant to the influence of fossil fuel use. It exerts a warming influence by decreasing the cooling power of the atmosphere. Emissions of CO_2 are accumulating in the atmosphere, as described in the following section, so that the warming influence is growing. Other greenhouse gases (methane, nitrous oxide, halogens, and ozone) act similarly, currently adding another 75 percent to CO_2 's warming. Aerosols exert an overall cooling effect, although with large uncertainties in the way they catalyze the formation of reflective clouds. As a result, understanding the causes of recent warming requires not just identifying the warming effects of CO_2 , but also the more uncertain cooling effects of aerosols.

The IPCC assesses the change in the radiative forcing by the sun to be negligible, based on their preference for data reconstructions that imply minimal solar change since preindustrial times. But Connolly *et al.* (2021) reviewed sixteen different Total Solar Irradiance (TSI) reconstructions in the literature

covering the years 1600-2000; the reconstructions vary from almost no change in TSI to a relatively large upward trend. Those authors note that the variation in TSI reconstructions combined with variations in surface temperature reconstructions allows for inferences consistent with either no or most 20th century warming being attributable to the sun.

A particularly thorny issue is the gap in TSI data between 1989 and 1991 due to a delay in the launch of a monitor following the Space Shuttle Challenger disaster on January 28 1986. This delay prevented a replacement satellite from being launched in time to overlap with, and its readings to be intercalibrated with, the prior system (Zacharias 2014, Scafetta *et al.* 2019). This is called the ACRIM (Active Cavity Radiometer Irradiance Monitor) gap problem. The question of whether there is an upward trend in TSI over 1978 to 2018 hangs on how the ACRIM data gap is filled. Connolly *et al.* (2021) found that the IPCC's consensus statements on solar forcing were formulated prematurely through the suppression of dissenting scientific opinions.

Another natural radiative forcing component is volcanic aerosols, which exert an episodic cooling influence. Box 4.1 in the IPCC AR6 Report addresses the climate impact of volcanic eruptions, noting three explosive volcanic eruptions that occurred in the first half of the 19th century. This included the 1815 Tambora eruption that resulted in the ‘year without summer’, with multiple harvest failures across the Northern Hemisphere. There is uncertainty about the sign of the relatively small forcing due to the submarine volcano Hunga Tonga which erupted in 2022 (Jenkins *et al.* 2023, Schoeberl *et al.* 2024).

Figure 3.1.1 shows that the anthropogenic forcing component was negligible before about 1900 and has increased steadily since, rising to almost 3 W/m² today. However, this is still only about 1 percent of the unperturbed radiation flows, making it a challenge to isolate the effects of anthropogenic forcing; state-of-the-art satellite estimates of global radiative energy flows are only accurate to a few W/m².

Natural sources of global energy imbalance other than volcanoes and total solar irradiance (TSI) are not included in these graphs because they remain largely unknown.

3.1.2 Change in atmospheric CO₂ since 1958

Carbon dioxide's warming influence depends on how much “extra” CO₂ accumulates in the atmosphere- *i.e.*, its concentration above the preindustrial value of 280 ppm. The CO₂ level as recorded at the Mauna Loa observatory in Hawaii, generally used as the representative global average concentration, is available online at [[HYPERLINK "https://gml.noaa.gov/ccgg/trends/index.html"](https://gml.noaa.gov/ccgg/trends/index.html)]. The concentration was about 316 ppm at the start of the record in 1959 and is now about 430 ppm, a 36 percent increase. At the end of the last glaciation CO₂ levels had fallen to about 180 ppm. As discussed in Chapter 2, C3 plants begin dying at CO₂ levels below about 140 ppm and C4 plants at levels below 100 ppm, so if CO₂ levels had continued falling plant life would have been imperiled.

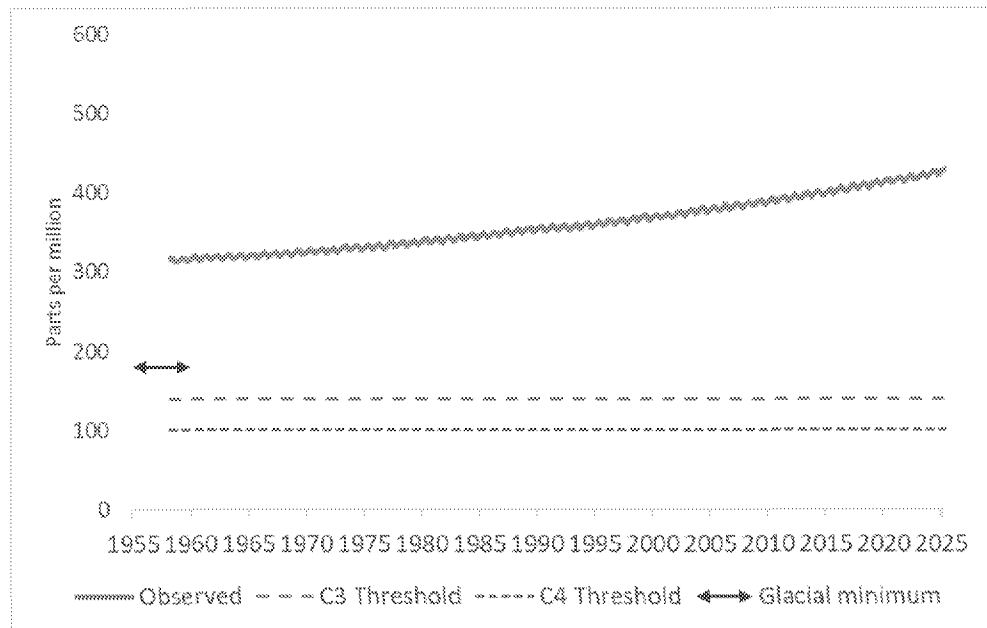


Fig. 3.1.3. Yearly average atmospheric CO₂ concentrations (1959-2025) in ppm measured at Mauna Loa (blue). C3 Threshold: Level below which C3 plants begin dying (140 ppm, see Chapter 2). C4 Threshold: Level below which C4 plants begin dying (100 ppm, see Chapter 2). Glacial minimum: Minimum level during recent glaciations (purple arrow). CO₂ data source: [HYPERLINK "<https://gml.noaa.gov/ccgg/trends/index.html>"]

The annual increase in concentration is only about half of the CO₂ emitted because land and ocean processes currently absorb “excess” CO₂ at a rate approximately 50 percent of the human emissions. Future concentrations, and hence future human influences on the climate, therefore depend upon two components: (1) future rates of global human CO₂ emissions, and (2) how fast the land and ocean remove extra CO₂ from the atmosphere. We discuss each of these in turn.

3.2 Future emission scenarios and the carbon cycle

3.2.1 Emission scenarios

Assessing the dangers of future GHG emissions requires assumptions about what those emissions will be. Future emissions, and hence human influences on the climate, will depend upon future demographics, economic activity, regulation, and energy and agricultural technologies. Various assumptions about each of those lead to projections of greenhouse gas emissions and concentrations, aerosol concentrations, and changes in land use, which ultimately can be combined into assumptions about anthropogenic radiative forcing.

The great uncertainties about these many factors make it impossible to precisely predict future emissions. Instead, the IPCC has created various sets of scenarios meant to span a plausible range of possibilities for population, economy, and technologies. Recent versions of the scenarios are labeled by a number indicating the anthropogenic radiative forcing expected in 2100 under that scenario. Thus, a scenario labeled with a “6” corresponds to 6 W/m² of human-induced radiative forcing (warming) at the end of the century. (Recall current anthropogenic radiative forcing is about 2.7 W/m².)

Although the IPCC does not claim its emission scenarios are forecasts, they are often treated as such. Comparisons of past scenario groups against observations show that IPCC emission projections tend to overstate actual subsequent emissions. For the IPCC Third and Fourth Assessment Reports a set of emission projections from the *Special Report on Emission Scenarios* was used; these were referred to as the SRES scenarios. McKittrick *et al.* (2012) showed that, when converted to per capita values, the SRES scenario emissions distribution was skewed upwards and incompatible with observed trends. McKittrick and Wood (2013) further showed that global energy market dynamics constrained global per capita CO₂ emissions to an extent not reflected in IPCC scenarios. The bias of the SRES scenarios was confirmed by the later analysis of Hausfather *et al.* (2019) who showed that observed atmospheric CO₂ concentrations tracked the low end of the SRES range and also of subsequent IPCC scenario ranges (Figure 3.2.1).

For AR5 the IPCC developed a new set of scenarios called the Representative Concentration Pathways (RCPs). These were identified by a number representing the increase in forcing and were thus called RCP2.6, RCP4.5, RCP6.0 and RCP8.5. RCP2.6 (implying an anthropogenic radiative forcing in 2100 of 2.6 W/m²) describes a GHG concentration pathway leading to warming well below 2°C. At the other end of the scale RCP8.5 is an extreme outcome implying nearly 5°C warming from 1900 to 2100.

RCP8.5 came to be referred to as the no-policy baseline, or “business-as-usual” scenario in both the academic literature and popular media. It was therefore used to generate the reference outcome supposedly representing the 21st century world in the absence of increasingly stringent emission reduction policies. But RCP8.5 was intended as a low-probability high emissions scenario and its use as a business-as-usual baseline has been criticized as grossly misleading.¹ Hausfather and Peters (2020) writing in a commentary in *Nature*, pointed out that RCP8.5 was developed as an extreme worst-case, and its misuse as a “business as usual” baseline has resulted in a large number of misleading studies and media reporting.

The implausibility of the RCP8.5 scenario was examined by Burgess *et al.* (2021). They noted that RCP8.5 has already diverged from observed trends in energy use and the near future trends diverge sharply from those of the International Energy Agency (IEA), which provides market-based projections of energy use for the coming decades. The IEA trends, which are based on plausible extrapolations of current economic and demographic trends, run below the entire envelope of RCP projections, implying not only that RCP8.5 is dubious, but that even lower emission scenarios are unlikely.

Widespread use of RCP8.5 has created a bias towards alarm in the climate impacts literature. The extent of this problem was confirmed in a literature analysis by Pielke Jr. and Ritchie (2020). They found that some 16,800 scientific papers published between 2010 and 2020 used the RCP8.5 scenario, with about 4,500 of the articles linking RCP8.5 to the concept of “business-as-usual”. Their analysis showed how RCP8.5 was misused not only by individual researchers, but also by influential science agencies like the IPCC and the U.S. National Climate Assessment (USNCA), which has directly led to misleading coverage in prominent media outlets.

¹ This extreme scenario is useful for modelers, since a large forcing generates a large response (warming) making it easier to assess a model’s sensitivity. But that’s very different than claiming it is a plausible future outcome.

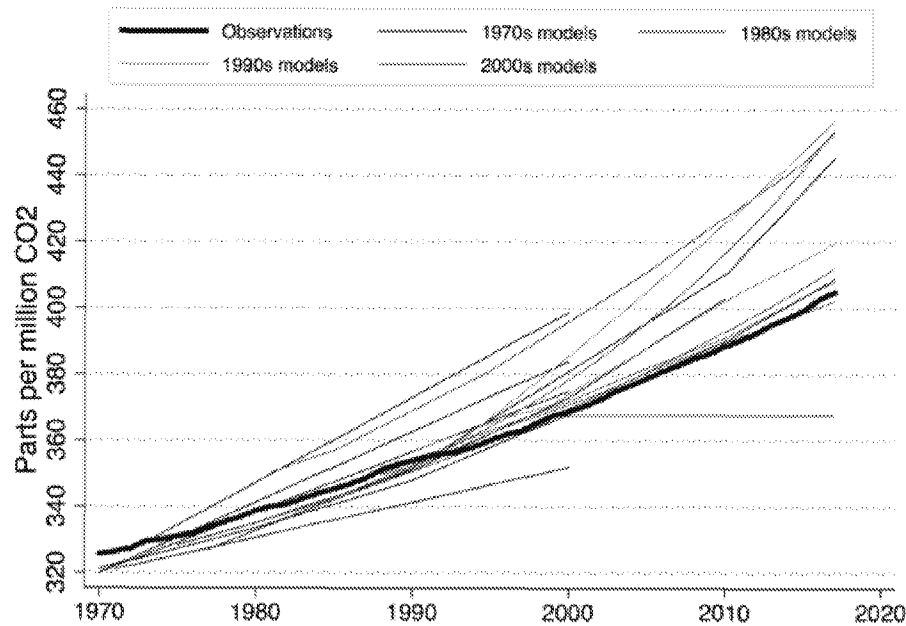


Figure 3.2.1 Comparison of observed atmospheric CO₂ levels (black line) with scenario projections (colored lines, mainly IPCC) since the 1970s. Source: Hausfather *et al.* (2019) Figure S4.

Pielke and Ritchie (2020) reported new studies using RCP8.5 were published at a rate of about 20 per day, with about two per day specifically linking RCP8.5 and “business as usual.” They conclude that the climate research community has spent a decade “committing scientific resources to science fiction” and that “The scientific literature has become imbalanced in an apocalyptic direction.”

The IPCC developed a new set of scenarios for AR6, the “Shared Socioeconomic Pathway” (SSP) scenarios, which have continued the bias shown in the RCP and SRES scenarios. Figure 3.2.2 shows total global observed CO₂ emissions compiled by the International Energy Agency (IEA) merged with the emission projection from the IEA taking account of energy use projections and current policies. The other lines show the range of IPCC SSP scenarios (SSP1-SSP5). As of 2023, global CO₂ emissions have been tracking well below SSP7.0 and are even below SSP2-4.5.

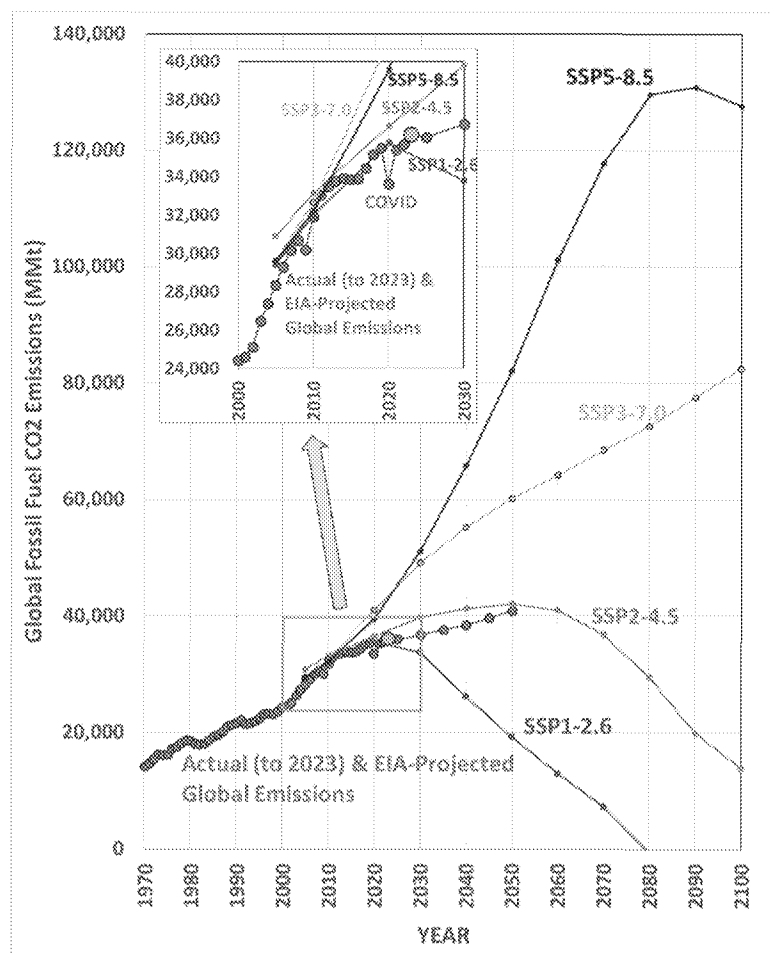


Figure 3.2.2. Observed and projected CO₂ emissions. Source: IPCC (SSP scenarios) and Energy Information Administration (EIA). Green: observed historical emissions and EIA projections. Other lines: SSP1-5. Data source: Friedlingstein *et al.* (2024).

3.2.2 The carbon cycle relating emissions and concentrations

Carbon dioxide emissions from fossil fuel burning (and to a lesser extent deforestation and cement production) have led to steadily increasing CO₂ concentrations in the atmosphere, as shown in Fig. 3.1.3. The relation between emissions and concentration is determined by the global carbon cycle of land and ocean processes that exchange carbon with the atmosphere. Our understanding of these processes was reviewed by Crisp *et al.* (2021).

There are about 850 Gt of carbon (GtC) in the Earth's atmosphere², almost all of it in the form of CO₂. Each year, biological processes (plant growth and decay) and physical processes (ocean absorption and outgassing) exchange about 200 GtC of that carbon with the Earth's surface (roughly 80 GtC with the land and 120 GtC with the oceans). Before human activities became significant, removals from the atmosphere were roughly in balance with additions. But burning fossil fuels (coal, oil, and gas) removes carbon from the ground and adds it to the annual exchange with the atmosphere. That addition (together with a much

² Because CO₂ is chemically transformed through the course of the carbon cycle, it is more convenient to track atoms of carbon rather than molecules of CO₂. One gigatonne of carbon (GtC) is equivalent to about 3.7 Gt of CO₂.

smaller contribution from cement manufacturing) amounted to 10.3 GtC in 2023, or only about 5 percent of the annual exchange with the atmosphere.

The carbon cycle accommodates about 50 percent of humanity’s small annual injection of carbon into the air by naturally sequestering it through plant growth and oceanic uptake, while the remainder accumulates in the atmosphere (Ciais *et al.*, 2013). For that reason, the annual increase in atmospheric CO₂ concentration averages only about half of that naively expected from human emissions.

To project future CO₂ concentrations in the atmosphere, and hence future human influences on the climate, it is important to know how the carbon cycle might change in the future. The historical near constancy of that 50 percent fraction means that the more CO₂ humanity has produced, the faster nature removed it from the atmosphere. That 50 percent fraction changes somewhat from year to year due to natural carbon cycle imbalances from El Nino, La Nina, and varying weather patterns. There was also a substantial additional reduction in atmospheric CO₂ after the 1991 eruption of Mt. Pinatubo, a curious result that has yet to be explained (Angert *et al.*, 2004).

The main processes that remove excess CO₂ from the atmosphere are increased growth of land vegetation (especially at high latitudes), some increase in the sequestering of carbon in soils, and uptake of CO₂ by the ocean due to the increasing partial pressure of atmospheric CO₂ over that of CO₂ dissolved in the ocean. All twenty land carbon cycle models tracked by the Global Carbon Project (Friedlingstein *et al.*, 2024) show land processes have been removing excess CO₂ at an increasing rate since 1959. This is consistent with a “global greening” phenomenon (Chapter 2.1) observed by satellites since monitoring of global greenness began in 1982.

While land vegetation has been responding positively to more atmospheric CO₂, uptake of extra CO₂ by ocean biological processes remains too uncertain to be measured reliably. Our current understanding of these and many more carbon cycle processes was reviewed by Crisp *et al.* (2021).

CO₂ uptake by land processes

The uptake of extra CO₂ from the atmosphere by land surface processes (as also inferred from global greening) has been modeled with 20 different dynamic global vegetation models, the outputs of which are updated every year by the Global Carbon Project (Friedlingstein, 2024). As seen in Fig. 3.2.3, all of those models agree that vegetation and soils have been sequestering carbon from the atmosphere. But we also see that the long-term trends over 1959 to 2023 (65 years) vary widely between models, by nearly a factor of 7. This demonstrates that there remains considerable uncertainty in how fast land processes are removing CO₂ from the atmosphere, which in turn creates uncertainty in future atmospheric CO₂ concentrations, which then produce uncertainty in climate model simulations of future climate change.

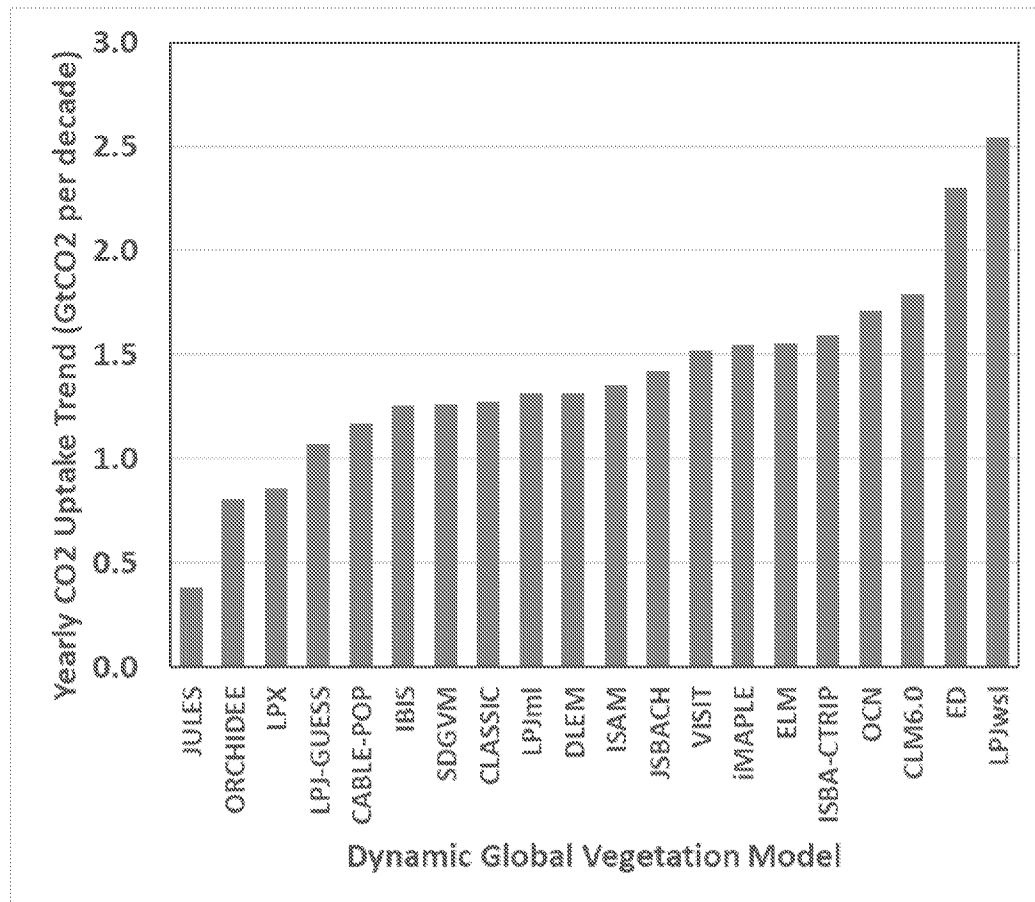


Figure 3.2.3 Trends of annual CO₂ uptake (GtCO₂ per year per decade) by land processes during 1959-2023 simulated by 20 different dynamic global vegetation models periodically reported by the Global Carbon Project (Friedlingstein, 2024).

CO₂ uptake by ocean processes

The uptake of extra CO₂ from the atmosphere by ocean processes has been modeled with 10 different ocean biogeochemistry models, the outputs of which are updated every year by the Global Carbon Project (Friedlingstein, 2024). Like the results from the land models, all of the ocean models agree that the global oceans have been sequestering carbon from the atmosphere at an increasing rate during 1959-2023 (Fig. 3.2.4). Unlike the land models, however, the ocean models show much better agreement with each other, with the model producing the fastest increasing CO₂ uptake being only 65 percent faster than the model with the most slowly increasing CO₂ uptake. In spite of the relative agreement among models, Friedlingstein *et al.* (2022) notes that there is substantial discrepancy between the different methods on the strength of the ocean sink over the last decade, particularly in the Southern Ocean.

Note that the average trend in CO₂ uptake across all land models in Fig. 3.2.3 is 25 percent larger than the average trend in ocean uptake. This suggests land processes are increasing in their ability to remove CO₂ faster than ocean processes are increasing their CO₂ sequestration.

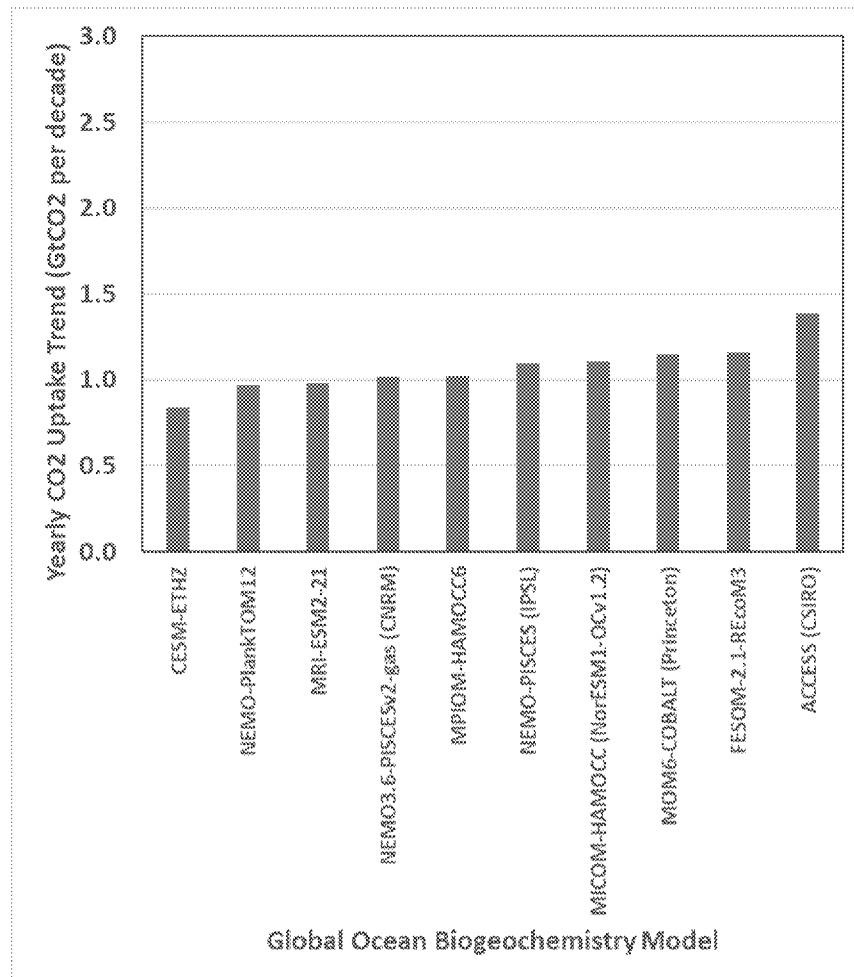


Figure 3.2.4 Trends of annual CO₂ uptake (GtCO₂ per year per decade) by ocean processes during 1959-2023 simulated by 10 different ocean biogeochemistry models periodically reported by the Global Carbon Project (Friedlingstein, 2024).

3.3 Urbanization influence on temperature trends

Historical temperature data over land has been collected mainly where people live. This raises the problem of how to filter out non-climatic warming signals due to Urban Heat Islands (UHI) and other changes to the land surface. If these are not removed the data might over-attribute observed warming to greenhouse gases. The IPCC acknowledges that raw temperature data are contaminated with UHI effects but claims to have data cleaning procedures that remove them. It is an open question whether those procedures are sufficient.

AR6 downplayed this issue by saying (WGI p. 235) that no recent evidence had emerged to alter the AR5 finding that urbanization causes an upward bias of no more than 10 percent in the global land surface warming trend. AR5 (WGI p. 189) also cited the 10 percent upper bound without citing a source. AR4 (WGI p. 244) cited Jones *et al.* (1990) and Peterson *et al.* (1999) as the basis of the claim. Peterson *et al.* had failed to find any difference in trends between rural and urban samples, although their definition of rural included local populations up to 10,000 persons while the relative influence of urbanization begins well below that (Spencer *et al.*, 2025). Jones *et al.* compared rural/urban warming in three regions: Eastern Australia, Eastern China and Western Soviet Union. Their definition of “rural” included towns of up to

10,000 in the former Soviet Union and up to 100,000 in China. They found relative warming biases greater than 10 percent in these areas but conjectured that the urbanization effect averaged over the areas they did not examine would bring the global land bias to under 10 percent of the observed warming trend.

Several papers appeared in print prior to the IPCC AR4 that argued that the warming effect of UHIs added a relatively large (30-50%) component to observed warming and was not simulated by climate models (de Laat and Maurellis 2006, McKittrick and Michaels 2007). These findings were based on correlations between locations of maximum warming over land with locations of maximum socioeconomic development. AR4 asserted (p. 244) that these correlations were an artefact of natural atmospheric circulations and were in fact statistically insignificant, and on that basis set the findings aside. Their claim was controversial because it was presented with no supporting evidence. McKittrick (2010) and McKittrick and Nierenberg (2010) showed that taking into account various conjectured alternative explanations for the correlations did not affect their significance. AR5 (p. 189) conceded that AR4 had provided “no explicit evidence” for its assessment and further acknowledged, based on these papers, that there was “significant evidence for such contamination of the record” i.e. a warming bias in the land record. However as already noted, elsewhere in the AR5 report they carried forward AR4 claim that it was less than 10 percent of observed warming. Further they provided no caution about using the land record for climate measurement despite conceding the evidence for UHI contamination. Recently Soon *et al.* (2023) estimated an urbanization bias in the Northern Hemisphere land record over 1850-2018 sufficient to increase the trend in the blended record from 0.55°C to 0.89°C per century.

Some studies providing evidence against UHI contamination compared warming rates between rural and urban locations (Jones *et al.* 1990, Peterson *et al.* 1999, Wickham *et al.* 2013). It is not known whether such methods would be capable of detecting UHI bias even when present. The influence of UHI warming is logarithmic in population, in other words it is strongest at low population density then levels off as local urbanization expands (Oke 1973, Spencer *et al.* 2025). Hence failure to find a difference in warming rates between urban and rural stations does not prove the absence of UHI contamination. McKittrick (2013) provided an empirical demonstration in which the rural/urban trends were not significantly different in a data set shown on other grounds to be contaminated with UHI bias.

Parker (2006) examined a sample of urban locations and found no difference in trends between subsets partitioned according to nighttime wind speed, concluding on this basis that urbanization could not be a significant factor. Here again the question is whether such a method would find UHI bias even if present. McKittrick (2013) presented an example in which UHI-contaminated data did not exhibit significant trend differences when stratified according to wind speed.

The challenge in measuring UHI bias is relating local temperature change to a corresponding change in population or urbanization, rather than to a static classification variable such as rural or urban. Spencer *et al.* (2025) used newly available historical population archives to undertake such an analysis and found evidence of significant UHI bias in U.S. summertime temperature data.

In summary, while there is clearly warming in the land record, there is also evidence that it is biased upward by patterns of urbanization and that these biases have not been completely removed by the data processing algorithms used to produce climate data sets.

References

- Angert, A., S. Biraud, Bonfils, C., Buermann, W. and I. Fung (2004). CO2 seasonality indicates origins of post-Pinatubo sink. *Geophysical Research Letters* 31. [[HYPERLINK "https://doi.org/10.1029/2004GL019760" \t "_blank" \]](https://doi.org/10.1029/2004GL019760)]
- AR6: *Intergovernmental Panel on Climate Change Sixth Assessment Report* (2021) Working Group I Contribution. [[HYPERLINK "http://www.ipcc.ch"](http://www.ipcc.ch)].

- AR5: *Intergovernmental Panel on Climate Change Fifth Assessment Report* (2021) Working Group I Contribution. [HYPERLINK "<http://www.ipcc.ch>"].
- AR4: *Intergovernmental Panel on Climate Change Fourth Assessment Report* (2021) Working Group I Contribution. [HYPERLINK "<http://www.ipcc.ch>"].
- Burgess, Matthew et al (2021) *Environmental Research Letters* 16 014016 [HYPERLINK "<https://iopscience.iop.org/article/10.1088/1748-9326/abcdd2/meta>"]
- Ciais, P., C. Sabine, G. Bala, L. Bopp, V. Brovkin, *et al.* (2013): Carbon and Other Biogeochemical Cycles. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, *et al.* (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA
- Connolly, Roman, Willie Soon, Michael Connolly *et al.* (2021) How much has the Sun influenced Northern Hemisphere temperature trends? An ongoing debate *Research in Astronomy and Astrophysics* 21(6) doi: 10.1088/1674-4527/21/6/131 [HYPERLINK "<https://iopscience.iop.org/article/10.1088/1674-4527/21/6/131>"]
- Crisp, David & Dolman, Han (A.J.) & Tanhua, Toste & McKinley, Galen & Hauck, Judith & Bastos, Ana & Sitch, Stephen & Eggleston, Simon & Aich, Valentin. (2022). How Well Do We Understand the Land-Ocean-Atmosphere Carbon Cycle?. *Reviews of Geophysics*. 60. 10.1029/2021RG000736.
- De Laat, A.T.J., and A.N. Maurellis (2006), Evidence for influence of anthropogenic surface processes on lower tropospheric and surface temperature trends, *International Journal of Climatology* 26:897—913.
- Friedlingstein, P., and 95 co-authors (2024): Global Carbon Budget 2024, *Earth System Science Data* 14(4), [HYPERLINK "<https://essd.copernicus.org/preprints/essd-2024-519>"]
- Hausfather *et al.* (2019) “Evaluating the Performance of Past Climate Model Projections” *Geophysical Research Letters* 47(1) [HYPERLINK "<https://doi.org/10.1029/2019GL085378>"]
- Hausfather, Z. and G. Peters (2020) “Emissions – the ‘business as usual’ story is misleading” *Nature* 29 January 2020 [HYPERLINK "<https://www.nature.com/articles/d41586-020-00177-3>"]
- Jenkins, S., Smith, C., Allen, M. *et al.* Tonga eruption increases chance of temporary surface temperature anomaly above 1.5 °C. *Nat. Clim. Chang.* 13, 127–129 (2023). [HYPERLINK "<https://doi.org/10.1038/s41558-022-01568-2>"]
- Jones, P. D., P. Y. Groisman, M. Coughlan, N. Plummer, W.-C. Wang, and T. R. Karl (1990), Assessment of urbanization effects in time series of surface air temperature over land, *Nature*, 347, 169 – 172
- Liu, Pengfei *et al.* (2021) “Improved estimates of preindustrial biomass burning reduce the magnitude of aerosol climate forcing in the Southern Hemisphere” *Science Advances* 7(22) May 2021 [HYPERLINK "<https://doi.org/10.1126/sciadv.abc1379>"]
- McKittrick, R.R. and P.J. Michaels (2007), Quantifying the influence of anthropogenic surface processes and inhomogeneities on gridded global climate data, *Journal of Geophysical Research*, 112, D24S09, doi:10.1029/2007JD008465.
- McKittrick, Ross and Joel Wood (2013) Co-fluctuation patterns of per capita carbon dioxide emissions: The role of energy markets. *Energy Economics* 39 pp. 1-12 [HYPERLINK "<https://www.sciencedirect.com/science/article/abs/pii/S0140988313000649>"]
- McKittrick, Ross R. (2010) [HYPERLINK "<https://www.rossmckitrick.com/uploads/4/8/0/8/4808045/spp.publishedversion.pdf>" \t "_blank"] [HYPERLINK "<http://www.degruyter.com/view/j/spp.2010.1.1/issue-files/spp.2010.1.issue-1.xml>"] Vol 1. No. 1., July 2010
- McKittrick, Ross R. (2013) Encompassing Tests of Socioeconomic Signals in Surface Climate Data. *Climatic Change* doi 10.1007/s10584-013-0793-5. Volume 120, Issue 1-2. [HYPERLINK "<http://link.springer.com/article/10.1007%2Fs10584-013-0793-5>"]
- McKittrick, Ross R. and Nicolas Nierenberg (2010) [HYPERLINK "https://www.rossmckitrick.com/uploads/4/8/0/8/4808045/final_jesm_dec2010.formatted.pdf"]. [

- HYPERLINK "<http://iospress.metapress.com/content/n83k07278212/>"], 35(3,4) pp. 149-175. DOI 10.3233/JEM-2010-0336
- McKittrick, Ross R., Mark Strazicich and Junsoo Lee (2012) “[HYPERLINK "<http://onlinelibrary.wiley.com/doi/10.1002/for.2248/abstract>" \t "_blank"]” *Journal of Forecasting*, Vol 32, Issue 5, pp 435-451 DOI: 10.1002/for.2248.
- Oke, T.R., 1973: City size and the urban heat island, *Atmospheric Environment* 7, 769-779
- Parker, D.E. (2006) “A Demonstration that Large-Scale Warming is not Urban.” *Journal of Climate* 19:2882—2895.
- Peterson, Thomas C., Kevin P. Gallo, Jay Lawrimore, Timothy W. Owen, Alex Huang, David A. McKittrick (1999) Global rural temperature trends. *Geophysical Research Letters* February 1999 [HYPERLINK "<https://doi.org/10.1029/1998GL900322>"]
- Pielke, Roger and Ritchie, Justin (2020) “Systemic Misuse of Scenarios in Climate Research and Assessment” Social Sciences Research Network April 2020, available at: [HYPERLINK "<https://ssrn.com/abstract=3581777>"]
- Scaffeta, Nicola, Richard C. Willson, Jae N. Lee and Dong Wu (2019) Modeling Quiet Solar Luminosity Variability from TSI Satellite Measurements and Proxy Models during 1980–2018. *Remote Sensing* 11(21) 2569 [HYPERLINK "<https://doi.org/10.3390/rs11212569>"]
- Schoeberl, M.R., Y. Wang, G. Taha, D.J. Zawada, R. Ueyama and A. Dessler, 2024. Evolution of the climate forcing during the two years after the Hunga Tonga-Hunga Ha’apai eruption. *J. Geophys. Res.*, 129.
- Soon, W.; Connolly, R.; Connolly, M.; Akasofu, S.-I.; Baliunas, S.; *et al.* (2023) The Detection and Attribution of Northern Hemisphere Land Surface Warming (1850–2018) in Terms of Human and Natural Factors: Challenges of Inadequate Data. *Climate* 2023, 11, 179. [HYPERLINK "<https://doi.org/10.3390/cli11090179>"]
- Spencer, Roy W, John R Christy and William D. Braswell (2025) Urban Heat Island Effects in U.S. Summer Surface Temperature Data, 1895–2023 *Journal of Applied Meteorology and Climatology* April 2025 [HYPERLINK "<https://doi.org/10.1175/JAMC-D-23-0199.1>" \t "_blank"]
- Wickham C, R Rohde , RA Muller, J Wurtele, J Curry, *et al.* (2013) Influence of Urban Heating on the Global Temperature Land Average using Rural Sites Identified from MODIS Classifications. *Geoinformatics and Geostatistics: An Overview* 1:2.
- Zacharias, Pia (2014) An Independent Review of Existing Total Solar Irradiance Records. *Surveys in Geophysics* 35 pp. 897—912 [HYPERLINK "<https://link.springer.com/article/10.1007/s10712-014-9294-y>"]

PART II: CLIMATE RESPONSE TO CO₂ EMISSIONS

4 CLIMATE SENSITIVITY TO CO₂ FORCING

Chapter Summary

There is growing recognition that climate models are not fit for the purpose of determining the Equilibrium Climate Sensitivity (ECS) of the climate to increasing CO₂. The IPCC has turned to data-driven approaches including historical data and paleoclimate reconstructions, but their reliability is diminished by data inadequacies.

Data-driven ECS estimates tend to be lower than climate model-generated values. The IPCC AR6 upper bound for the likely range of ECS is 4.0°C, lower than the AR5 value of 4.5°C. This lowering of the upper bound seems well justified by paleoclimatic data. The IPCC AR6 lower bound for the likely range of ECS is 2.5°C, substantially higher than the AR5 value of 1.5°C. This raising of the lower bound is less justified; evidence since the AR6 finds the lower bound of the *likely* range to be around 1.8°C.

4.1 Introduction

The climate's response to increasing concentrations of CO₂ is central to the scientific debate on anthropogenic climate change, and so also to the public debate on “climate action.” The simplest measure of that response is the rise in the global average surface temperature, quantified by the Equilibrium Climate Sensitivity (ECS). ECS is defined as the amount of warming expected in response to a doubling of CO₂ from its pre-industrial concentration of 280 ppm, after all climate components have had time to adjust. Some components, like temperatures in the lower atmosphere (troposphere), adjust rapidly, while others such as the deep ocean and cryosphere might take as long as centuries. A related measure, the Transient Climate Response (TCR), better describes the shorter time scales; it is defined as the amount of warming when the CO₂ concentration is doubled by rising one percent annually for 70 years.

The 1979 Charney Report for the U.S. National Academy of Sciences (National Research Council 1979) proposed that the most likely ECS was $3.0 \pm 1.5^\circ\text{C}$. The IPCC repeatedly reaffirmed that range with only minor variations until its most recent AR6. AR5 termed 1.5–4.5°C as the *likely* range (66 percent probability) and stated that ECS is *extremely unlikely* (95 percent probability) to be below 1.0°C and *very unlikely* (90 percent probability) to exceed 6.5°C.

The uncertainty in ECS has remained stubbornly wide, despite many individual studies that claimed to narrow it (Hausfather 2023). Most recently, AR6 narrowed the *likely* range to 2.5–4.0°C and deemed the *very likely* range to be 2.0–5.0°C. This narrowing on the low end is disputed, as will be discussed below.

Uncertainties in ECS are highly consequential for policy making. As will be discussed in Chapter 11, economic models use ECS values to project the costs of CO₂ emissions. The traditional value (3.0 °C) has typically yielded modest global social costs of CO₂ emissions, sufficient to justify some policy actions, but mostly deferred to later in this century. If ECS is very high (above 4.5°C) immediate aggressive emission controls become more imperative, whereas no CO₂ emission controls are economically justifiable for ECS below 2.0°C (Dayaratna *et al.* 2016, 2020). Obtaining a precise estimate is impossible, so policy making needs to account for the uncertainty.

By itself, the equilibrium warming effect of a doubling of atmospheric CO₂ is slightly more than 1°C (Soden and Held 2006). Larger values of ECS arise from positive feedbacks that amplify the CO₂ warming. Water vapor feedback is positive: a warmer atmosphere might have more water vapor, which itself is a powerful greenhouse gas. Warmer temperatures also result in less snow and sea ice cover, allowing the

Earth to absorb more of the sun's radiation. Some simple estimates of these feedbacks increase the ECS to around 2°C (Sherwood *et al.*, 2020). Larger values of ECS are associated with positive cloud feedbacks.

Climate scientists use multiple lines of evidence to determine the Equilibrium Climate Sensitivity:

- Climate model simulations
- Historical observations
- Paleoclimatic reconstructions
- Process understanding of feedbacks

4.2 Model-based estimates of climate sensitivity

The ECS ranges given in IPCC AR4 and AR5 were obtained primarily by examining the behavior of large-scale climate models, also called General Circulation Models (GCMs). However, the IPCC changed course in its AR6 when it turned to a more direct data-driven methodology. Here we discuss some of the pitfalls of using GCMs to try to determine the Earth's climate sensitivity.

In principle, ECS is an emergent property of GCMs—that is, it is not directly parameterized or tuned, but rather emerges in the results of the simulation. Otherwise plausible GCMs and parameter selections have been discarded because of perceived conflict with an expected warming rate, or aversion to a model's climate sensitivity being outside an accepted range (Mauritsen *et al.* 2012). This practice was commonplace for the models used in AR4; modelers have moved away from this practice with time. However, even in a CMIP6 model, Mauritsen and Roeckner (2020) state the following regarding their Max Planck Institute (MPI) climate model (emphasis added):

“We have documented how we tuned the MPI-ESM1.2 global climate model to match the instrumental record of warming; an endeavor which has clearly been successful. Due to the historical order of events, the choice was to do this practically by **targeting an ECS of about 3 K using cloud feedbacks**, as opposed to tuning the aerosol forcing.”

In other words, the MPI modelers chose an ECS value of 3°C and then tuned the cloud parameterizations to match their intended result.

As noted, direct warming from CO₂ doubling is only about 1°C (Soden and Held 2006); further warming arises from climate feedbacks that are not explicitly resolved by the GCM but rely on parameterizations of physical processes. Higher values of ECS arise primarily from assumed positive cloud feedbacks, whereas the magnitude and even the sign of the feedbacks are very uncertain. Elements of cloud feedback include changes in the latitudinal distribution of clouds, changes in the distribution of cloud height (changes in low versus high clouds), changes to the phase of clouds (ice versus liquid), changes in cloud particle size (associated with changes in concentration and/or composition of aerosol particles), changes in the precipitation efficiency of clouds, and even changes in how clouds are distributed over the daily solar cycle (Curry and Webster, 1999). It is difficult for GCMs to simulate any of these processes correctly owing to their small scale, let alone predict how they will change in the future. Further, cloud processes modulate the magnitudes of the water vapor, lapse rate, and the surface albedo feedbacks.

ECS can be determined from climate model simulations by doubling the concentration of CO₂ and allowing several centuries for the warming to equilibrate. To avoid the need for such long simulations, “effective climate sensitivity” is commonly evaluated from a 150-year simulation in response to a sudden quadrupling of CO₂.

The spread of ECS values from the CMIP5 ensemble of climate models used in AR5 was 2.0–4.7°C; that range increased for the CMIP6 models used in AR6 to between 1.8 and 5.7°C (Chen *et al.*, 2021, Scafetta 2021, see Figure 4.1). Far from resolving the model-based climate sensitivity the range appears to be growing. The main cause of the overall upward shift in ECS in CMIP6 relative to CMIP5 is a larger positive cloud feedback, driven by changes to the cloud parameterizations in many CMIP6 models (Zelinka *et al.*, 2020)

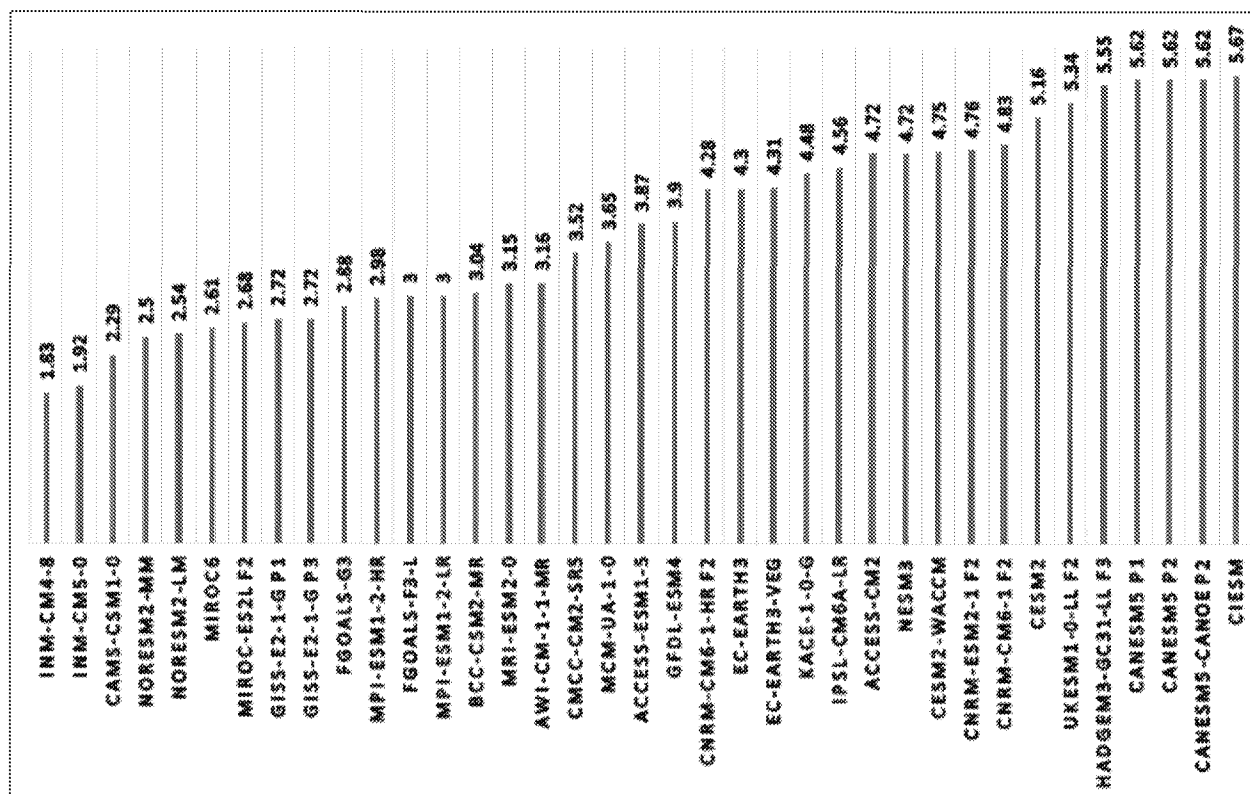


Figure 4.1 Equilibrium Climate Sensitivities in °C of 37 climate models from the CMIP6 ensemble. Identifiers for the various models appear along the horizontal axis. From (Scafetta, 2021)

Because of concerns about model tuning and the high sensitivity to cloud parameterizations, the IPCC AR6(2021) did not rely on climate model simulations in their assessment of climate sensitivity, relying instead on data-driven methods.

4.3 Data-driven estimates of climate sensitivity

Climate sensitivity can also be estimated from instrumental records of surface temperatures and ocean heat content, combined with estimates of how climate forcings (e.g., greenhouse gases, solar, volcanoes, aerosols) have changed in the past (Otto *et al.*, 2013). Using this information, a simple empirical model called an Energy Balance Model can be employed. It requires estimating a feedback parameter whose uncertainties are highly amplified in the resulting ECS (Roe and Baker, 2007).

The accuracy of the data-driven methods depends on the quality of the input data. Assumptions are needed about ocean heat storage, and good data is only available for recent decades. The greatest source of uncertainty is the amount and composition of aerosol particles and their interactions with cloud radiative properties (the so-called aerosol indirect effect; see Figures 3.1.1, 3.1.2). Climate models exhibit warming in response to GHGs but cooling in response to aerosols (Schwartz *et al.*, 2007). Observed 20th century warming can be shown to be consistent either with low ECS and low aerosol cooling, or high ECS and high aerosol cooling. Since fossil fuel use adds both GHGs and aerosols to the atmosphere, both effects need to be estimated to isolate the warming effect of CO₂.

Paleoclimate proxies are also used to evaluate the sensitivity of past climates by comparing paleoclimate changes in the Earth's temperatures to estimates of changes in forcings. The two most informative periods are the last glacial maximum (around 20,000 years ago), which was about 3–7°C colder than today, and a mid-Pliocene period (roughly three million years ago), which was 1–3°C warmer than today. The limits on cooling during the last glacial maximum give the best single evidence that high values of climate sensitivity are unlikely. However, paleoclimate estimates are associated with very large uncertainties in the estimated temperatures and forcings. Further, estimates of climate sensitivity based on past climate states might not be applicable to the current state of the climate system.

A recurring theme in the climate literature is that ECS estimates based on historical data are smaller than ECS estimates inferred from climate models (Sherwood and Forest 2024). About 15 estimates based on historical data appeared in the peer-reviewed literature between 2012 and 2024 yielding ECS best estimates between 1.0°C and 2.5°C, although critics have questioned some of the methods and the data quality. For AR6, the IPCC placed primary weight on the results of Sherwood *et al.* (2020) that combined historical data and paleoclimate proxies with the process-based approach and yielded a best estimate of 3.1°C with a *likely* range of 2.6–3.9°C. Lewis (2022) raised a number of concerns about this result, including methodological errors, outdated input values, and use of subjective Bayesian priors in the analysis. Lewis' analysis found that climate sensitivity is estimated to be much lower and better constrained than in the Sherwood *et al.* analysis – median 2.2°C (1.8–2.7°C in the 17–83 percent *likely* range, and 1.6–3.2°C in the 5–95 percent *very likely* range). The IPCC AR6 estimated only a 5 percent probability that ECS was below 2.3°C, whereas Lewis estimated it to be over 50 percent. The most recent publications on the debate between Sherwood *et al.* and Lewis further defend their respective positions: Sherwood and Foster (2024) and Lewis (2025).

An argument emphasized in AR6 is that data-driven ECS estimates might understate the future warming response to GHGs because of a so-called “pattern effect” (Forster *et al.*, 2021). The tropical Pacific is believed to strongly influence the overall efficiency with which the Earth radiates heat to space, but some regions remove heat more efficiently than others. If the west-to-east temperature gradient in the tropical Pacific is weakened in a warming climate, warming would concentrate where heat is less efficiently removed, raising ECS.

Most climate models simulate that rising GHGs will weaken the west-east temperature gradient, which led the IPCC in AR6 to conclude that data-driven ECS estimates understated the *future* ECS value. However, Seager *et al.* (2019) pointed out that, contrary to models, the west-east temperature gradient has been strengthening over time. They further argued that the mechanism predicting otherwise in climate models was based on a faulty characterization of oceanic dynamics and there is no reason to expect the gradient to weaken. A similar argument was recently made by Lee *et al.* (2024), who concluded that “the trajectory of the observed trend reflects the response to increasing GHG loading in the atmosphere”; in other words, GHG warming should lead to a future strengthening rather than a weakening of the temperature gradient. Increased efficiency of atmospheric cooling implies, if anything, that the future ECS in a warming climate might be *lower* than current estimates.

4.4 Transient Climate Response

The Transient Climate Response (TCR) provides a more useful observational constraint on climate sensitivity. TCR is the global temperature increase that results when CO₂ is increased at an annual rate of 1 percent over a period of 70 years (*i.e.*, doubled gradually). Relative to the ECS, observationally determined values of TCR avoid the problems of uncertainties in ocean heat uptake and the fuzzy boundary in defining equilibrium arising from a range of timescales for the longer-term feedback processes (*e.g.*, ice sheets). TCR is more generally related to peak warming and better constrained by historical warming, than ECS. IPCC AR6 judged the *very likely* range of TCR to be 1.2–2.4°C. In contrast to ECS, the upper bound of TCR is more tightly constrained. For comparison, the TCR values determined by Lewis (2023) are 1.25 to 2.0°C, showing much better agreement with AR6 values than was seen in a comparison of the ECS values.

References

- Carbon Brief. (2020, July 22). Explainer: How scientists estimate climate sensitivity. [HYPERLINK "https://www.carbonbrief.org/explainer-how-scientists-estimate-climate-sensitivity"]
- Carbon Brief. (2020, July 22). Guest post: Why low-end ‘climate sensitivity’ can now be ruled out. [HYPERLINK "https://www.carbonbrief.org/guest-post-why-low-end-climate-sensitivity-can-now-be-ruled-out"]
- Carbon Brief. (2021, August 9). In-depth Q&A: The IPCC’s sixth assessment report on climate science. [HYPERLINK "https://www.carbonbrief.org/in-depth-qa-the-ipccs-sixth-assessment-report-on-climate-science"]
- Chen, D., *et al.* (2021). Framing, context, and methods. In V. Masson-Delmotte *et al.* (Eds.), *Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.
- Curry, J. A., & Webster, P. J. (1999). Thermodynamic feedbacks in the climate system. In *Thermodynamics of atmospheres and oceans* (pp. 351–385). Academic Press.
- Dayaratna, Kevin, Ross McKittrick and David Kreutzer (2017) Empirically-Constrained Climate Sensitivity and the Social Cost of Carbon. *Climate Change Economics* April 2017 DOI: [HYPERLINK "http://dx.doi.org/10.1142/S2010007817500063"]
- Dayaratna, Kevin, Ross McKittrick and Patrick J. Michaels (2020) Climate Sensitivity, Agricultural Productivity and the Social Cost of Carbon in FUND. *Environmental Economics and Policy Studies* https://doi.org/10.1007/s10018-020-00263-w
- Forster, P., *et al.* (2021). The Earth’s energy budget, climate feedbacks, and climate sensitivity. In V. Masson-Delmotte *et al.* (Eds.), *Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.
- Hausfather, Z. (2020, July 22). Explainer: How scientists estimate climate sensitivity. Carbon Brief. [HYPERLINK "https://www.carbonbrief.org/explainer-how-scientists-estimate-climate-sensitivity"]
- Lan, X., Tans, P., & Thoning, K. W. (2025). Trends in globally-averaged CO₂ determined from NOAA Global Monitoring Laboratory measurements. NOAA Global Monitoring Laboratory. [HYPERLINK "https://doi.org/10.15138/9N0H-ZH07"]
- Lee, S., Byrne, M. P., Loikith, P. C., & O’Dell, C. W. (2024). Zonal contrasts of the tropical Pacific climate predicted by a global constraint. *Climate Dynamics*, 62(1–2), 229–246. [HYPERLINK "https://doi.org/10.1007/s00382-023-06741-7"]
- Lewis, N. (2023). Objectively combining climate sensitivity evidence. *Climate Dynamics*, 61(9–10), 3155–3163. [HYPERLINK "https://doi.org/10.1007/s00382-022-06398-8"]
- Lewis, N. (2025). Comment on “Can uncertainty in climate sensitivity be narrowed further?” by Sherwood and Forest (2024). *EGUsphere* [preprint]. [HYPERLINK "https://doi.org/10.5194/egusphere-2025-1179"]

- Thorsten Mauritsen et al., (2012) “Tuning the Climate of a Global Model,” *Journal of Advances in Modeling Earth Systems* 4, no. 3 <https://doi.org/10.1029/2012ms000154>
- Mauritsen, T., & Roeckner, E. (2020). Tuning the MPI-ESM1.2 global climate model to improve the match with instrumental record warming by lowering its climate sensitivity. *Journal of Advances in Modeling Earth Systems*, 12, e2019MS002037. [HYPERLINK "<https://doi.org/10.1029/2019MS002037>"]
- Otto, A., Otto, F. E. L., Boucher, O., Church, J., Hegerl, G., Forster, P. M., Gregory, J. M., & Johnson, G. C. (2013). Energy budget constraints on climate response. *Nature Geoscience*, 6(6), 415–416. [HYPERLINK "<https://doi.org/10.1038/ngeo1836>"]
- Pachauri, R. K., & Meyer, L. (Eds.). (2015). Climate change 2014: Synthesis report. *Intergovernmental Panel on Climate Change*.
- Roe, G. and M. Baker (2007). Why is climate sensitivity so unpredictable? *Science* 318, 629–632. [HYPERLINK "<https://doi.org/10.1126/science.1144735>"]
- Scafetta, N. (2021). Testing the CMIP6 GCM simulations versus surface temperature records from 1980–1990 to 2011–2021: High ECS is not supported. *Climate*, 9(11), 161. [HYPERLINK "<https://doi.org/10.3390/cli9110161>"]
- Schwartz, S. E., R. J. Charlson, H. Rodhe (2007). Quantifying climate change—Too rosy a picture? *Nature Climate Change* 1, 23–24, [HYPERLINK "<https://doi.org/10.1038/climate.2007.22>"]
- Seager, R., Cane, M., Ting, M., Naik, N., Clement, A., DiNezio, P., & Lee, D. E. (2019). Strengthening tropical Pacific zonal sea surface temperature gradient consistent with rising greenhouse gases. *Nature Climate Change*, 9(7), 517–522. [HYPERLINK "<https://doi.org/10.1038/s41558-019-0505-x>"]
- Sherwood, S. C., & Forest, C. E. (2024). Opinion: Can uncertainty in climate sensitivity be narrowed further? *Atmospheric Chemistry and Physics*, 24(5), 2679–2686. [HYPERLINK "<https://doi.org/10.5194/acp-24-2679-2024>"]
- Sherwood, S. C., Bony, S., Boucher, O., Bretherton, C. S., Forster, P. M., Gregory, J. M., & Stevens, B. (2020). An assessment of Earth's climate sensitivity using multiple lines of evidence. *Reviews of Geophysics*, 58(4). [HYPERLINK "<https://doi.org/10.1029/2019rg000678>"]
- Soden, B. J., and I.M. Held (2006). An assessment of climate feedbacks in coupled ocean–atmosphere models. *Journal of Climate*, 19(14), 3354–3360. [HYPERLINK "<https://doi.org/10.1175/jcli3799.1>"]
- Zelinka, M. D., Myers, T. A., McCoy, D. T., Po-Chedley, S., Caldwell, P. M., Ceppi, P., Klein, S. A., & Taylor, K. E. (2020). Causes of higher climate sensitivity in CMIP6 models. *Geophysical Research Letters*, 47, e2019GL085782. [HYPERLINK "<https://doi.org/10.1029/2019GL085782>"]

5 MODELS VERSUS OBSERVATIONS IN THE RECENT PAST

Chapter summary

Climate models show warming biases in many aspects of their reproduction of the past several decades. In response to estimated changes in forcing they produce too much warming at the surface (except in the models with lowest ECS), too much warming in the lower-and mid-troposphere and too much amplification of warming aloft.

Climate models also produce too much recent stratospheric cooling, invalid hemispheric albedos, too much snow loss, and too much warming in the Corn Belt. The IPCC has acknowledged some of these issues but not all.

5.1 Introduction

Climate models are the primary tool used to project future climate changes in response to increasing atmospheric levels of anthropogenic greenhouse gases. To assess the fitness of climate models for this purpose, it is reasonable to ask how well they reproduce the current climate and its variations over the past century. The box “Climate modeling” gives some detail on how climate models work.

Of great concern is the fact that, after several decades of the climate modeling enterprise involving approximately three dozen models operated by research centers around the world, the range of future warming they produce in response to a hypothetical doubling of atmospheric CO₂ extends over a factor of three, as we discussed in the previous chapter. This range of disagreement among models has not decreased for decades.

Problems with climate models are not just in their disagreement over the future, but also in their ability to replicate the recent past. Here we review some of the most important metrics of climate model accuracy: ability to reproduce historical surface, tropospheric and stratospheric temperature trends; ability to reproduce the vertical warming profile; and ability to reproduce other climate features such as snowfall. In all cases a persistent finding is that models on average err on the side of too much warming in response to estimated historical forcings.

BOX: Climate modeling

Most climate models, except for the simplest ones, represent Earth's land surface using a grid of squares on the order of 100 km wide. To simulate the atmosphere, typically 30 or more grid boxes are stacked above these squares. The ocean is modeled using a similar but finer grid, resulting in tens of millions of grid boxes for the atmosphere and oceans.

The computer models, based on physical laws, calculate how air, water, and energy move between grid boxes over time. The time step can be as small as 10 minutes, and repeating this process millions of times allows the simulation of climate over centuries. Running these models, even on the most powerful supercomputers, can take months. Comparing simulation results with historical climate data helps assess the accuracy of a model, while projections into the future estimate climate changes under assumed human and natural influences.

Despite sounding straightforward, climate modeling is highly complex. Many critical processes occur at scales smaller than the grid size. For instance, the flows of sunlight and heat in the atmosphere depend strongly on cloud cover. Since tracking individual clouds is impractical, researchers must make “subgrid” assumptions about the distribution of clouds in each grid box. Snow and ice cover, which affects how much sunlight is reflected or absorbed by the surface, is another subgrid factor.

Each subgrid assumption requires numerical parameters, which must be carefully set. Modelers initially estimate these parameters based on physics and observed climate patterns, then run the model. Because early results often diverge significantly from real-world observations, they “tune” these parameters to better match observed climate features. Different modeling teams use distinct assumptions and tuning strategies, leading to varied outcomes. Tuning is a necessary but delicate aspect of climate modeling, as it is for any complex system. Poor tuning can result in inaccurate simulations, while excessive tuning risks artificially steering results toward predetermined conclusions.

The spread of model representations of the current climate is very wide. One of the most basic indicators—Earth's average surface temperature—varies by about 3°C across CMIP6 models prior to 1880 (Figure 5.1), narrows slightly until 2040 then diverges to over 4 °C. For comparison 20th century warming was only about 1.0°C. This variation suggests substantial differences among models' physical processes.

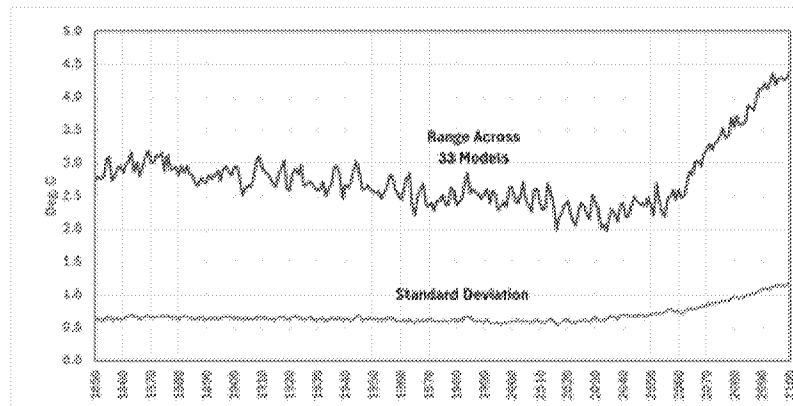


Figure 5.1 CMIP6 Average surface temperature range across 33 models and standard deviation using SSP5-85 scenario. Data from KNMI Climate Explorer website at [[HYPERLINK "https://climexp.knmi.nl/start.cgi" \t "_blank"](https://climexp.knmi.nl/start.cgi?_blank)].

Beyond the models' ability to reproduce features of today's climate, the critical issue for society is how well they predict responses to subtle human influences, such as greenhouse gas emissions, aerosol cooling, and land-use changes. The most crucial aspect that models must capture correctly is “feedbacks.” These occur when climate changes either amplify or suppress further warming. In general, the modeled net effect of all feedbacks doubles or triples the direct warming impact of CO₂.

5.2 Surface warming

A straightforward test of a climate model's validity is its ability to reproduce historical warming in response to known past changes in climate drivers such as greenhouse gases. Figure 5.2 is reproduced from Scafetta (2023), that groups the latest-generation (CMIP6) climate models into low ECS (1.5 to 3.0 degrees C), medium ECS (3.0 to 4.5 degrees C) and high ECS (4.5 to 6.0 degrees C), and compares their post-1980 global average temperature simulation ranges to those of three surface temperature records and one satellite-based lower troposphere temperature data product.

The leftmost column shows that the low-ECS models track the post-1980 historical warming record reasonably well, but the middle and right columns show that the medium- and high-ECS models conspicuously over-predict the warming.

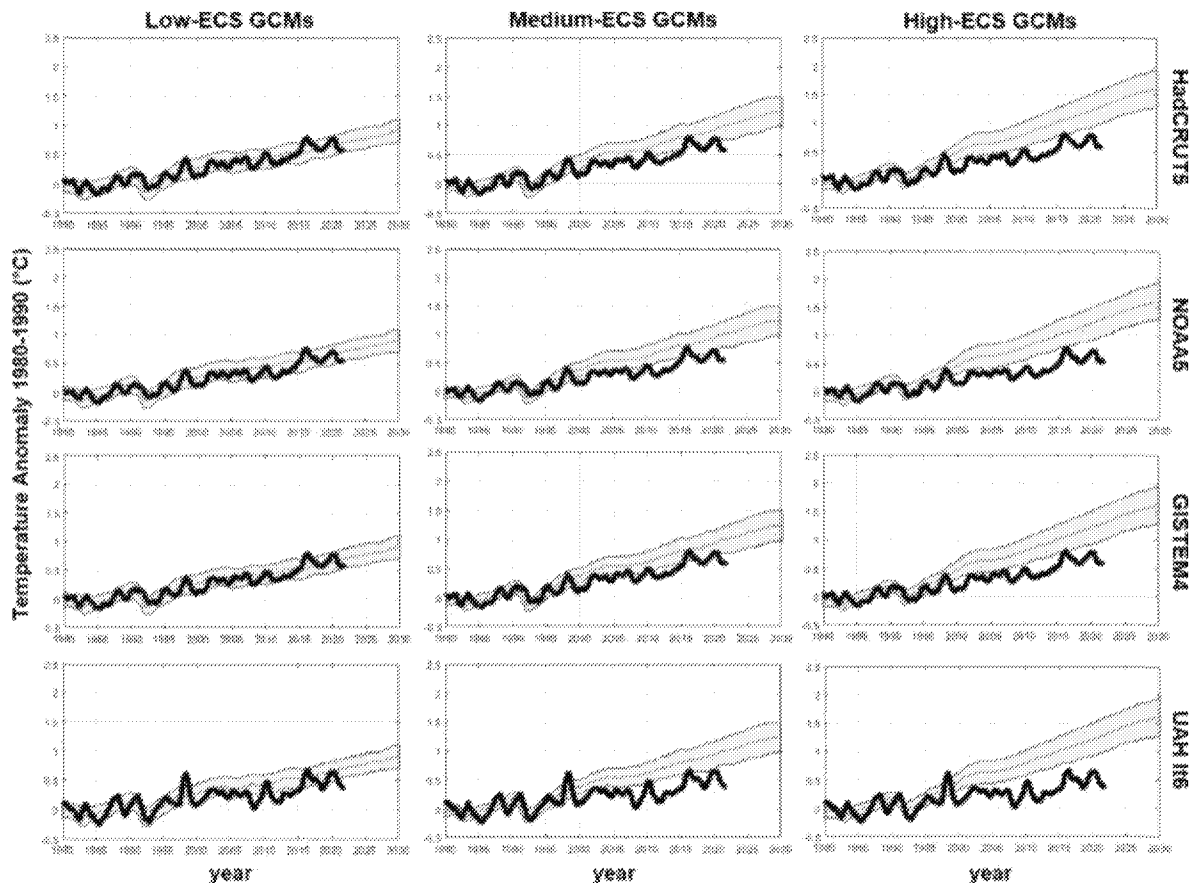


Figure 5.2: Model-Observational comparisons for Earth's surface warming. The columns correspond to model groups showing low-ECS to high-ECS, while the rows correspond to widely-used observed temperature records, the first three showing surface averages and the fourth showing the lower troposphere average. In each panel the yellow area denotes the mean and range ($\pm$ one standard deviation) of climate model simulations for that group. The thick black line shows the observed annual average temperature in the indicated source. Source: Scafetta (2023) Fig.2.

Spencer (2024) has also provided a useful summary of the Model-Observation mismatch by comparing trends in surface temperature data products with those in individual climate models, as summarized in Figure 5.3; most climate models show substantially more warming than the observations since 1979.

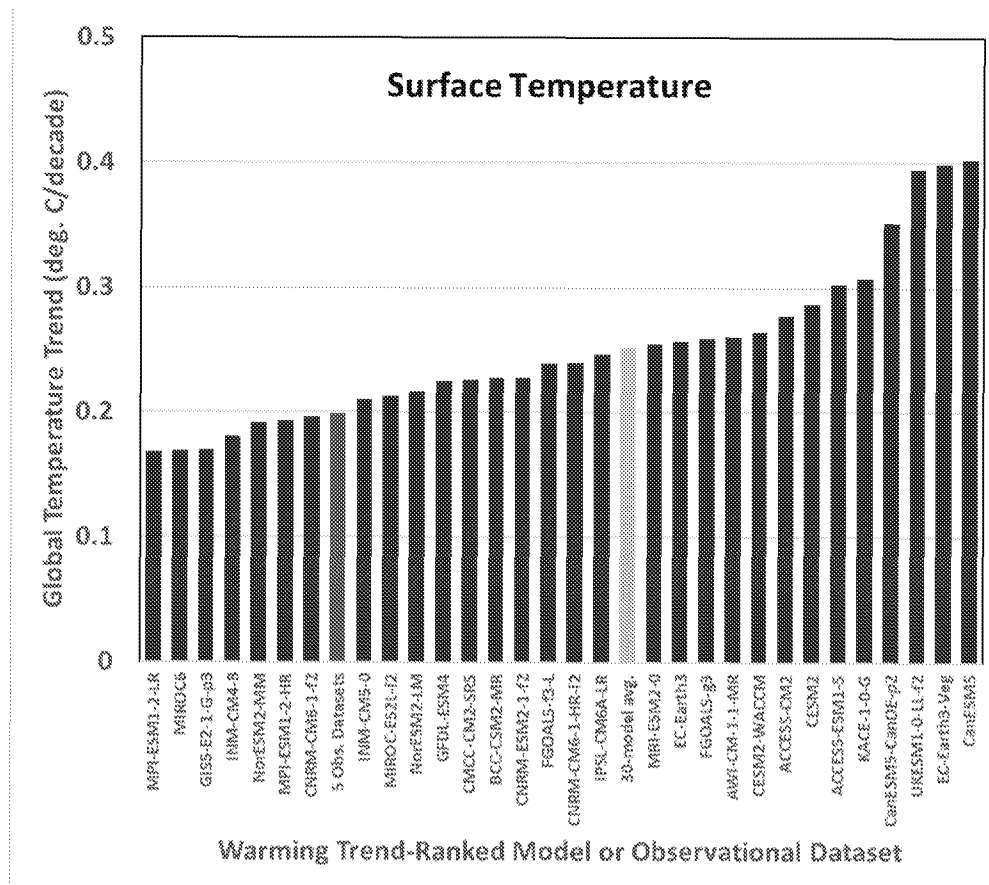


Figure 5.3 Global surface air temperature trends ($^{\circ}\text{C}/\text{decade}$), 1979-2024, from various CMIP6 climate models (red, 30-model average in orange); and the average of three thermometer datasets (HadCRUT5, NOAA Global Temp, and Berkeley 1 deg.) and two reanalysis datasets (ERA5 and NCEP/NCAR R1) in blue. Data source: <https://climexp.knmi.nl/start.cgi>.

5.3 Tropospheric warming

It has long been known that climate models on average overstate warming in the tropical troposphere. This region is an important test of climate models since this is where the signal of anthropogenic greenhouse warming emerges first and most strongly. Biases in tropospheric trends indicate model flaws in heat transfer processes that carry over to surface warming biases.

The discrepancy was flagged as a serious inconsistency in the first U.S. Climate Change Science Program report (Karl *et al.* 2006) and has been mentioned in every IPCC report since, but the discrepancy has gotten worse over time, and the bias is now global. McKittrick and Christy (2020) compared tropospheric warming trends in CMIP6 climate models to observed trends from satellites, weather balloons and reanalysis systems. Every model overpredicted the average observed warming trend over 1979-2014 in both Lower- and Mid-Troposphere layers, both globally and in the tropics. In most individual models the bias was statistically significant and on average across models it was highly significant.

Figure 5.4 presents the comparisons with data updated to 2024 (McKittrick and Christy 2025). The recent warm years moved the observed trend up slightly and widened the trend confidence intervals but the overall pattern remains the same: model bias is towards too much warming, in most cases the difference is statistically significant and on average the bias is statistically highly significant. McKittrick and Christy (2020) also showed that the bias is larger in high-ECS models, but even the models with lower average ECS predict too much warming. If future climate models were to realistically represent global tropospheric warming, they would likely be less sensitive than even the low-ECS members of the CMIP6 ensemble.

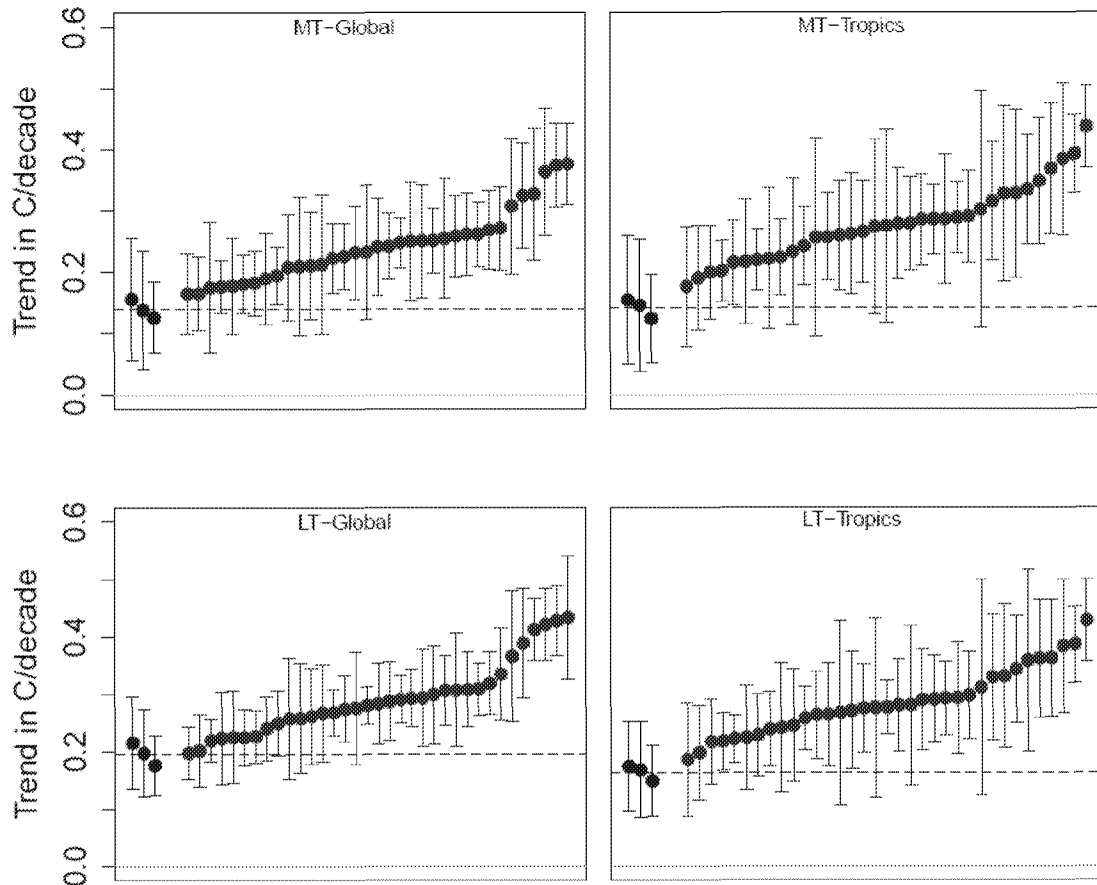


Figure 5.4: Observed versus CMIP6 modeled warming trends (°C/decade 1979-2024) in the global and tropical lower (LT) and mid-troposphere (MT). Uses methodology of McKittrick and Christy (2020) on data updated from 2014 to 2024. Blue dots: warming trends with 95 percent confidence intervals for 3 data products (radiosondes, reanalysis, and satellites). Blue dashed line: warming trend average for 3 observed series. Red dots: modeled warming trends with 95 percent confidence intervals in 35 models arranged lowest to highest.

As mentioned previously, the IPCC has long acknowledged the model-observation mismatch. For example, AR6 pp. 443-444 offers this on the tropical troposphere (it does not address the global comparison):

Several studies since AR5 have continued to demonstrate an inconsistency between simulated and observed temperature trends in the tropical troposphere, with models simulating more warming than observations (Mitchell *et al.*, 2013, 2020; Santer *et al.*, 2017a, b; McKittrick and Christy, 2018; Po-Chedley *et al.*, 2021)... Over the 1979–2014 period, models are more consistent with observations in the lower troposphere, and least consistent in the upper troposphere around 200 hPa, where biases exceed 0.1°C per decade. Several studies using CMIP6 models suggest that differences in climate sensitivity may be an important factor contributing to the discrepancy between the simulated and observed tropospheric temperature trends (McKittrick and Christy, 2020; Po-Chedley *et al.*, 2021), though it is difficult to deconvolve the influence of climate sensitivity, changes in aerosol forcing and internal variability in contributing to tropospheric warming biases (Po-Chedley *et al.*, 2021). Another study found that the absence of a hypothesized negative tropical cloud feedback could explain half of the upper troposphere warming bias in one model (Mauritsen and Stevens, 2015).

... In summary, studies continue to find that CMIP5 and CMIP6 model simulations warm more than observations in the tropical mid- and upper-troposphere over the 1979–2014 period (Mitchell *et al.*, 2013, 2020; Santer *et al.*, 2017a, b; Suárez-Gutiérrez *et al.*, 2017; McKittrick and Christy, 2018), and that overestimated surface warming is partially responsible (Mitchell *et al.*, 2013; Po-Chedley *et al.*, 2021). Hence, we assess with *medium confidence* that CMIP5 and CMIP6 models continue to overestimate observed warming in the upper tropical troposphere over the 1979–2014 period by at least 0.1°C per decade,

Notably, despite the accumulation of evidence of excess model warming the IPCC assigns only *medium confidence* to the existence of a warming bias.

5.4 Vertical temperature profile mismatch

Another important model-observational discrepancy is the excess amplification with altitude found in climate models. The comparison was in the IPCC AR5 Chapter 10, although only in the online supplement (Figure 10.SM.1) and only in a figure whose formatting obscured the point. Figure 10.SM.1 is not referenced in the main IPCC report nor in any summary so readers would not have been aware of it. Although not apparent at first glance, it shows that the 1979-2010 warming in the lower troposphere is so small as to be consistent with no GHG forcing at all and is inconsistent with the model runs that do have GHG forcing. In Figure 5.6 we adapt IPCC AR5 Figure 10.SM.1 to draw out this critical point.

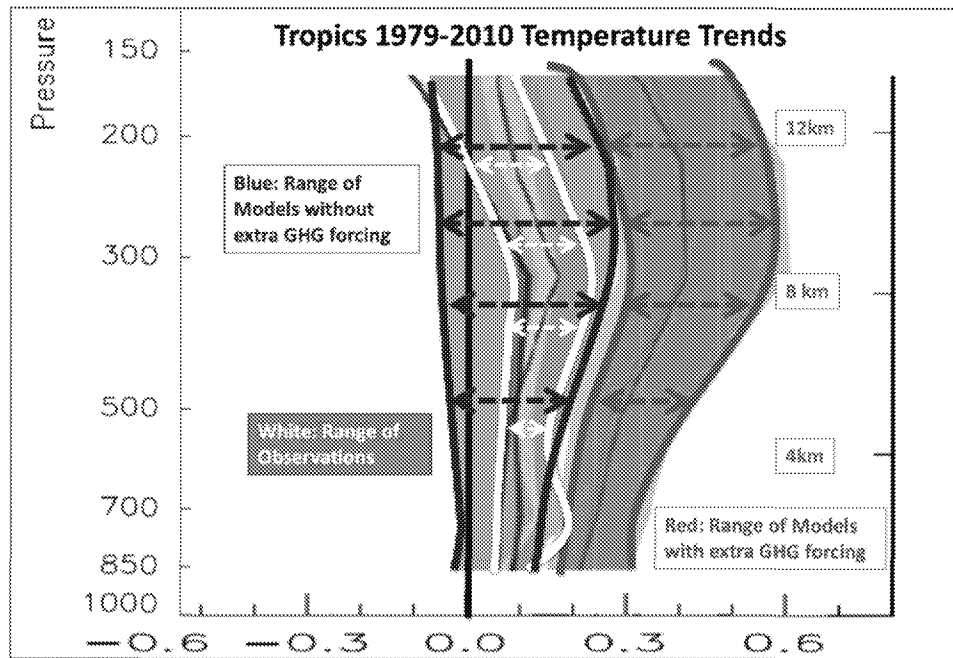


Figure 5.6: Vertical warming pattern for tropics (20S to 20N). Source: Annotated version of IPCC AR5 Figure 10.SM.1

Figure 5.6 compares model and observational temperature trends by altitude between 20S and 20N (the tropics). In this region where the models say the warming should be strongest, the observations (shown here in white) lie within the blue “No CO₂” band and entirely outside the “with CO₂” red envelope. This means that in the entire tropical atmospheric column from the surface to the base of the stratosphere, observed warming trends are so small as to be consistent with the output of models that have no anthropogenic CO₂, and inconsistent with the entire envelope of warming trends generated by models forced with increased CO₂.

A similar comparison is shown in Christy and McNider (2017), an updated version of which (covering 1979-2024) is reproduced as Figure 5.7. Modeled temperature trends exceed observations from the surface through the top of the troposphere, with observed trends below the entire model range at most pressure levels. Also shown in Figure 5.7 is the tropical tropospheric temperature (TTT) average from three satellite data products (NOAA, UAH and RSS) compared to the same layer average from climate models for 1979-2024. Again, the observed trends lie below the entire model range.

The wide range of choices made by modelers to characterize the physical processes in the models (see Box: Climate Modeling in Section 5.1 above) is seen by the large spread of trends in the middle troposphere, ± 40 percent about the median (Fig. 5.7). This vividly illustrates the uncertainties in attempts to model (parameterize) a complex system involving turbulence, moist thermodynamics, and energy fluxes over the full range of the tropical atmosphere’s time and space scales.

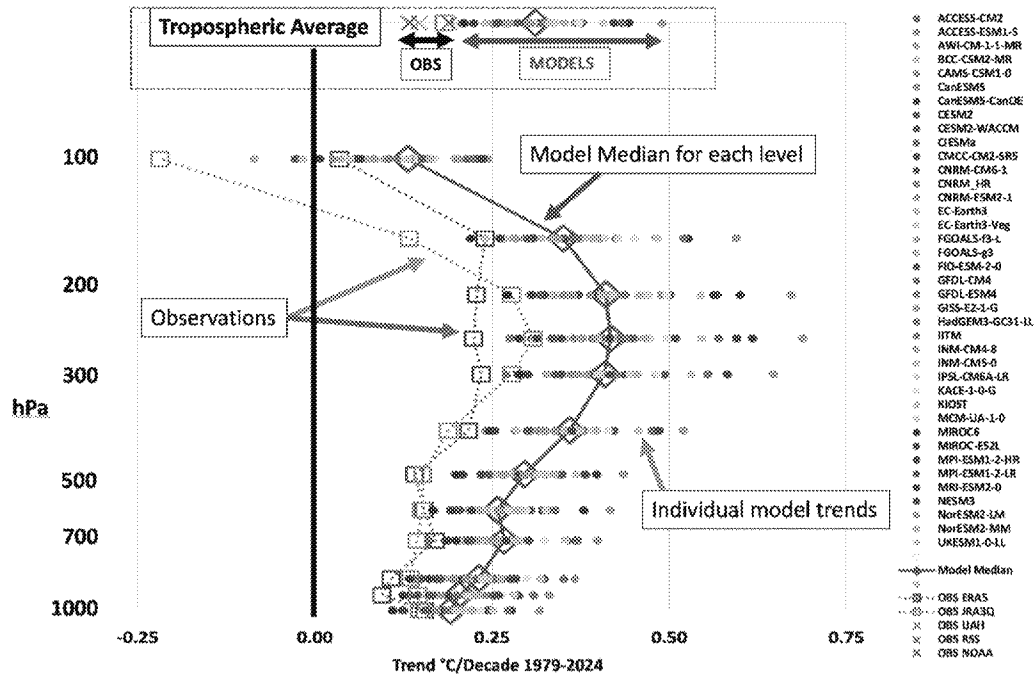


Figure 5.7: Modeled versus observed warming, tropical troposphere. Source: updated from Christy and McNider (2017) including data through 2024. Red line: model average. Green and blue lines: observational series (reanalysis).

This discrepancy has been the source of much controversy, with some arguing that even if there is very little observed warming aloft in the tropics, a “hotspot” still exists in the sense that the warming aloft is greater than at the surface (Santer et al. 2008). But there is good evidence that models also exaggerate the amplification rate. Klotzbach *et al.* (2009), showed that models project greater amplification with altitude than is observed. This result was subsequently confirmed by detailed time series analysis (Vogelsang and Nawaz 2016) which found that the model-observational difference is statistically significant.

The atmosphere’s temperature profile is a case where models are not merely uncertain but also show a common warming bias relative to observations. This suggests that they misrepresent certain fundamental feedback processes.

The IPCC AR6 did not assess this issue.

5.5 Stratospheric cooling

An important element of the expected general “fingerprint” of anthropogenic climate change is simultaneous warming of the troposphere and cooling of the stratosphere. AR6 acknowledged that cooling had been observed but only until the year 2000. The stratosphere has shown some warming since, contrary to model projections.

AR6 WG1 Ch 2 pp. 327-9 states:

Temperatures averaged through the full lower stratosphere (roughly 10–25 km) have decreased over 1980–2019 in all data products, with the bulk of the decrease prior to 2000. The decrease holds even if the influence of the El Chichon (1982) and Pinatubo (1991) volcanic eruptions on the trend,

found by Steiner *et al.* (2020a) to have increased the 1979–2018 cooling trend by 0.06°C per decade, is removed. Most datasets show no significant or only marginally significant trends over 2000–2019, and the results of Philipona *et al.* (2018) show weak increases over 2000–2015 in the very lowermost stratosphere sampled by radiosondes....

It is virtually certain that the lower stratosphere has cooled since the mid-20th century. However, most datasets show that lower stratospheric temperatures have stabilized since the mid-1990s with no significant change over the last 20 years. It is likely that middle and upper stratospheric temperatures have decreased since 1980, but there is low confidence in the magnitude.

The cited source, Philipona *et al.* (2018), in an article entitled “Radiosondes Show That After Decades of Cooling, the Lower Stratosphere Is Now Warming”, stated:

In response to continued greenhouse gas increases and stratospheric ozone depletion, climate models project continued tropospheric warming and stratospheric cooling over the coming decades. Global average satellite observations of lower stratospheric temperatures exhibit no significant trends since the turn of the century. In contrast, an analysis of vertically resolved radiosonde measurements from 60 stations shows an increase of lower stratospheric temperature since the turn of the century at altitudes between 15 and 30 km and over most continents. Trend estimates are somewhat sensitive to homogeneity assessment choices, but all investigated radiosonde data sets suggest a change from late twentieth century cooling to early 21st century warming in the lower stratosphere.

A combination of tropospheric warming and stratospheric cooling is a commonly cited “fingerprint” of anthropogenic warming. Stratospheric warming since 2000 coincides with continued surface and tropospheric warming, a pattern that is not found in climate model simulations and is not apparently consistent with the anthropogenic fingerprint.

5.6 Snow cover mismatch

Data compiled by the Rutgers University Snow Lab show that Northern Hemisphere winter snow cover is not decreasing (Figure 5.8); if anything, it shows an increasing trend.

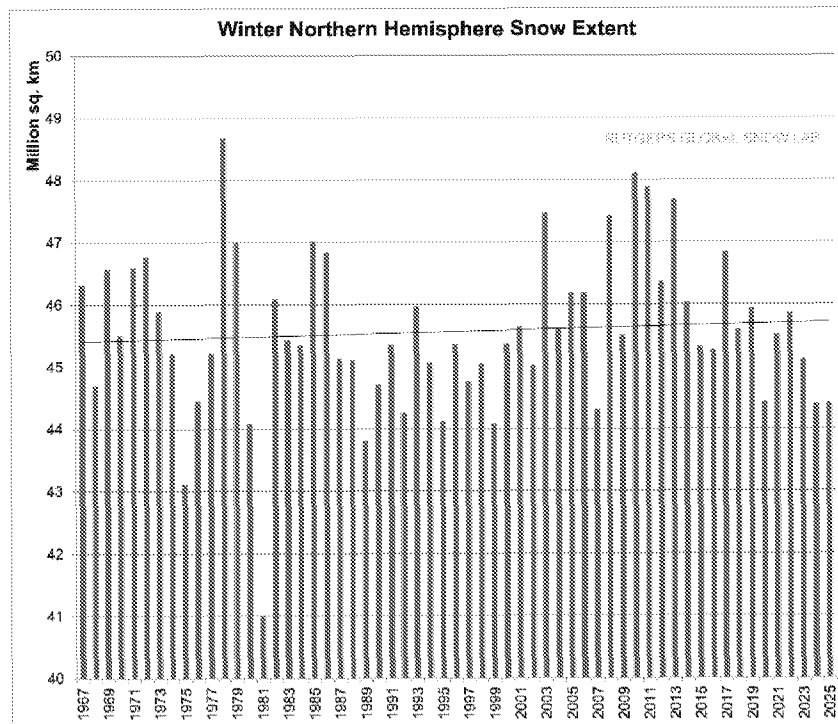


Figure 5.8: Northern Hemisphere Winter Snow extent.

Source: [[HYPERLINK](https://climate.rutgers.edu/snowcover/chart_seasonal.php?ui_set=nhland&ui_season=1)]

"https://climate.rutgers.edu/snowcover/chart_seasonal.php?ui_set=nhland&ui_season=1"]
(accessed May 27, 2025)

Yet models project declining Northern Hemisphere snow cover in a warming climate, as described by Connolly *et al.* (2019).

The climate models were found to poorly explain the observed trends [in Northern Hemisphere snow cover]. While the models suggest snow cover should have steadily decreased for all four seasons, only spring and summer exhibited a long-term decrease, and the pattern of the observed decreases for these seasons was quite different from the modelled predictions. Moreover, the observed trends for autumn and winter suggest a long-term increase, although these trends were not statistically significant.

AR6 largely confines its discussion of changing Northern Hemisphere snow cover extent (SCE) to the Spring season, for which models and observations agree on a downward trend. Regarding Winter changes it remarks as follows (AR6 WGI Ch. 2 p. 344):

Assessment of SCE trends in the NH since 1978 indicates that for the October to February period there is substantial uncertainty in trends with the sign dependent on the observational product. Analysis using the NOAA Climate Data Record shows an increase in October to February SCE (Hernández-Henríquez *et al.*, 2015; Kunkel *et al.*, 2016) while analyses based on satellite borne optical sensors (Hori *et al.*, 2017) or multi-observation products (Mudryk *et al.*, 2020) show a negative trend for all seasons.

AR6 WGI Chapter 9 (p. 1284) points out that the NOAA Climate Data Record showing increased fall and winter SCE is inconsistent with land-based observations and model-based data sets. It notes that using optical satellite imagery to infer SCE in winter is challenging due to cloud cover and decreased solar illumination in winter months. Focusing on the Pacific Coast states (CA, OR and WA) cold season mountain snowfall that melts in spring and summer provides a substantial portion of warm season water resources. A comprehensive reconstruction of snowfall for the main source regions (Cascades and Sierra Nevada Mountains) indicates no significant trends in annual totals since the late 19th century (Christy 2022).

In summary, the up-to-date Rutgers SCE database indicates a mismatch between models and observations. Further work to reconcile conflicting trends in observational data sets is required.

5.7 Hemispheric symmetry of the planetary albedo

The planetary albedo is the fraction of incoming solar radiation reflected by the Earth back to space. It is an important element of the radiative energy balance and influences whether the planet will warm or cool over time. The planetary albedo is typically estimated at around 0.30; variations on the scale of 0.01 correspond to changes in solar forcing of about 3 W/m^2 , an amount larger than current anthropogenic forcing. It has long been noted that models disagree with each other and with observations on the value of the global planetary albedo (Stephens *et al.* 2015).

An intriguing property of the Earth's albedo is that, on average, the Northern Hemisphere (NH) and Southern Hemisphere (SH) have had nearly the same albedo, at least throughout the fifty-year satellite record (Stephens *et al.*, 2015). This symmetry is surprising, because the SH has much more ocean than land. Since ocean is less reflective than land, the NH should have higher albedo. Clouds (which are highly reflective) are more common in the NH and so compensate the surface albedo imbalances of the two hemispheres. Datseris and Stephens (2021) show that this cloud compensation comes from the extra-tropical storm tracks of the SH, which are cloudier than those of the NH. While the mechanism for this hemispheric symmetry is unclear, it likely operates on large temporal and spatial scales.

The hemispheric symmetry of the albedo is a simple gross metric for climate models. Rugenstein and Hakuba (2023) defined that metric as the difference between the NH and SH annual mean albedos, expressed as Wm^{-2} of the reflected sunlight, and compiled it for the CMIP6 climate models, as shown in Figure 5.9. Most of the CMIP6 models do not reproduce the small observed asymmetry (about 0.1 Wm^{-2}) and even disagree as to which hemisphere is more reflective. Moreover, the magnitude of the asymmetry ranges up to 5 Wm^{-2} in some models, twice as large as the current anthropogenic forcing (about 2.5 Wm^{-2}).

The significance of unphysical albedo asymmetries in the climate models is not yet fully known. However, other model studies suggest that interhemispheric changes in albedo can alter poleward heat fluxes, meridional temperature gradients, storminess, and differences in hemispheric ocean heat storage. The discrepancy between models and observations further raises issues regarding cloud feedback processes and so more generally diminishes confidence in model projections of the future climate.

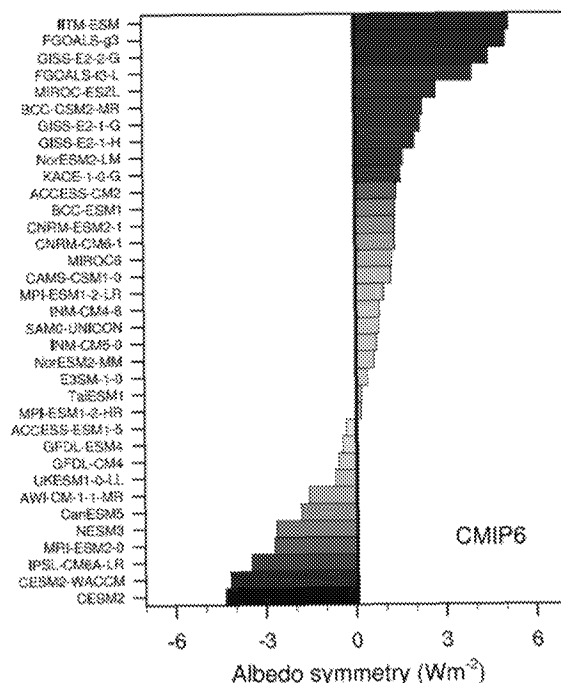


Figure 5.9. Differences in 20-year average reflectivity (albedo) between the Northern and Southern Hemispheres for CMIP6 models used in the most recent IPCC assessment (colored bars). The very small observed difference is indicated by the vertical black line. From Rugenstein and Hakuba (2023).

5.8 U.S. Corn Belt

One of the largest discrepancies between models and observations is in the U.S. Corn Belt, a region of particular importance to global food production. Figure 5.10 shows the warming trends for summertime (June, July, August) for the 12-state Corn Belt (IN, IA, IL, ND, SD, MO, MN, WI, MI, OH, KS, NE) during 1973-2022. All 36 climate models (red) warm far too rapidly compared to observations (blue).

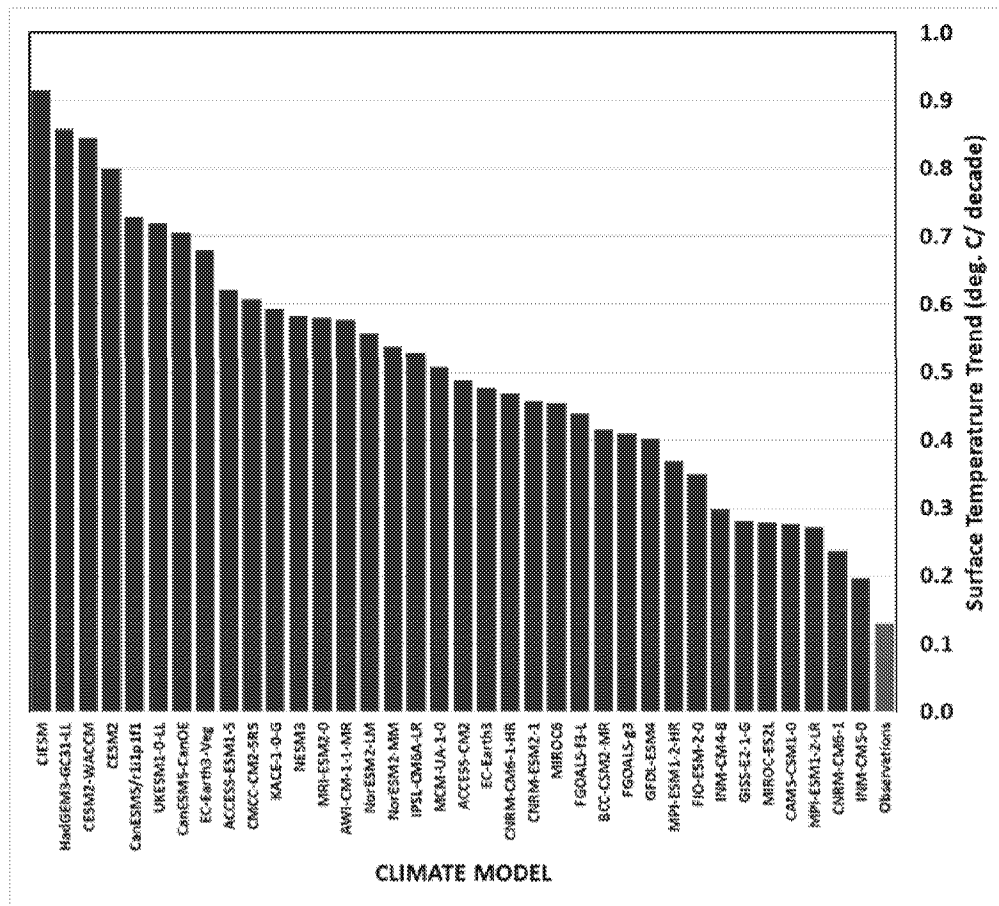


Figure 5.10: Modeled versus observed warming trends in the U.S. Corn Belt, 1973-2022.

As discussed in Chapter 9, the anticipated negative effects of increasing temperatures on U.S. corn yields have not materialized, in contrast to widely publicized studies proclaiming that theoretical future impacts are already being experienced (*e.g.*, Seager *et al.*, 2018).

The IPCC acknowledges limitations in the accuracy of regional climate model outputs. This example shows that users need to assess model projections carefully on a case-by-case basis since local biases might be sufficiently large that the models are simply not fit for purpose. As has recently been noted by two leaders of the modeling community (emphasis added)

... for many key applications that require regional climate model output or for assessing large-scale changes from small scale processes, we believe that **the current generation of models is not fit for purpose**. (Palmer and Stevens 2019)

To summarize:

- Climate models show warming biases in many aspects of their reproduction of the past few decades.
- They produce too much warming at the surface (except in the models with lowest ECS), too much warming in the lower-and mid-troposphere and too much amplification of warming aloft
- They also produce too much stratospheric cooling, too much snow loss, and too much warming in the U.S. Corn Belt.

- The hemispheric albedo difference in individual climate models ranges widely in sign and magnitude compared to observations. The range in W/m^2 is three times larger than the direct anthropogenic forcing of CO_2 .
- The IPCC has acknowledged some of these issues but not others.

References

- Christy, J. R., R. T. McNider (2017). Satellite bulk tropospheric temperatures as a metric for climate sensitivity. *Asia-Pacific Journal of Atmospheric Sciences* 53, 511-518. [HYPERLINK "<https://doi.org/10.1007/s13143-017-0070-z>"]
- Christy, J. R. (2022). Time series construction of Oregon and Washington snowfall since 1890 and an update of California snowfall through 2020. *Journal of Hydrometeorology* 23, 1845-1860. [HYPERLINK "<https://doi.org/10.1175/JHM-D-21-0178.1>"]
- Connolly, R., M. Connolly, W. Soon, *et al.* (2019). Northern Hemisphere snow-cover trends (1967–2018): A comparison between climate models and observations. *Geosciences* 9, 135. [HYPERLINK "<https://doi.org/10.3390/geosciences9030135>"]
- Datseris, G., B. Stevens (2021). Earth's albedo and its symmetry. *AGU Advances* 2, e2021AV000440. [HYPERLINK "<https://doi.org/10.1029/2021AV000440>"]
- Karl, T.R., S. J. Hassol, C. D. Miller, W. L. Murray, eds. (2006). Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences. U.S. Climate Change Science Program/Subcommittee on Global Change Research. [HYPERLINK "https://digital.library.unt.edu/ark:/67531/metadc12017/m2/1/high_res_d/sap1-1-final-all.pdf"]
- Klotzbach, P.J., R. A. Pielke, Sr., R. A. Pielke, Jr., J. R. Christy, R. T. McNider (2009). An alternative explanation for differential temperature trends at the surface and in the lower troposphere. *Journal of Geophysical Research — Atmospheres* 114(D21). [HYPERLINK "<https://doi.org/10.1029/2009JD011841>"]
- McKittrick, R. and J. R. Christy (2020). Pervasive warming bias in CMIP6 tropospheric layers. *Earth and Space Science* 7. [HYPERLINK "<https://doi.org/10.1029/2020EA001281>"]
- McKittrick, R., and J.R. Christy (2025), "Data and Code for DoE Report 2025", Mendeley Data, V1, doi: 10.17632/8n9ks93vn7.1
- Palmer, T., and B. Stevens (2019). The scientific challenge of understanding and estimating climate change. *Proceedings of the National Academy of Sciences* 116(49), 24390–24395. [HYPERLINK "<https://doi.org/10.1073/pnas.1906691116>"]
- Philippona, R., C. Mears, M. Fujiwara, *et al.* (2018). Radiosondes show that after decades of cooling, the lower stratosphere is now warming. *Journal of Geophysical Research — Atmospheres* 123. [HYPERLINK "<https://doi.org/10.1029/2018JD028901>"]
- Rugenstein, M., and M. Hakuba (2023). Connecting hemispheric asymmetries of planetary albedo and surface temperature. *Geophysical Research Letters* 50, e2022GL101802. [HYPERLINK "<https://doi.org/10.1029/2022GL101802>"]
- Santer B D, P.W. Thorne, L Haimberger *et al.* (2008) Consistency of modelled and observed temperature trends in the tropical troposphere *International Journal of Climatology* 28 1703–22 [HYPERLINK "<https://rmets.online.library.wiley.com/doi/abs/10.1002/joc.1756>"]
- Scaffeta, N (2023) CMIP6 GCM ensemble members versus global surface temperatures. *Climate Dynamics* 60, 3091–3120 (2023). [HYPERLINK "<https://doi.org/10.1007/s00382-022-06493-w>"]

- Seager, R., J. Feldman, N. Lis, *et al.* (2017). Whither the 100th meridian? The once and future physical and human geography of America's arid-humid divide. Part II: The meridian moves east. *Earth Interactions* 22. [HYPERLINK "<https://doi.org/10.1175/EI-D-17-0012.1>"]
- Spencer, R. W. (2024). Global warming: Observations vs. climate models. Environment Backgrounder, The Heritage Foundation.
[HYPERLINK "<https://www.heritage.org/environment/report/global-warming-observations-vs-climate-models>"]
- Stephens, G. L., D. O'Brien, P.J. Webster *et al.* (2015). The albedo of Earth. *Reviews of Geophysics*.
[HYPERLINK "<https://doi.org/10.1002/2014RG000449>"]
- Vogelsang, T. and N. Nawaz (2016). Estimation and inference of linear trend slope ratios with an application to global temperature data: *Journal of Time Series Analysis* 38. [HYPERLINK "<https://doi.org/10.1111/jtsa.12209>"]

6 EXTREME WEATHER

Chapter Summary

Most types of extreme weather exhibit no statistically significant long-term trends over the available historical record. While there has been an increase in hot days in the U.S. since the 1950s, a point emphasized by AR6, numbers are still low relative to the 1920s and 1930s. Extreme convective storms, hurricanes, tornadoes, floods and droughts exhibit considerable natural variability, but long-term increases are not detected. Some increases in extreme precipitation events can be detected in some regions over short intervals but the trends do not persist over long periods and at the regional scale. Wildfires are not more common in the U.S. than they were in the 1980s. Burned area increased from the 1960s to the early 2000's, however it is low compared to the estimated natural baseline level. U.S. wildfire activity is strongly affected by forest management practices.

6.1 Introduction

High impact weather extremes, usually related to temperature, precipitation and/or high wind, can disrupt infrastructure and therefore endanger human health and wellbeing. The issue is not whether extremes occur. Rather, it is whether there are long-term (decadal scale) changes in the frequency or character of extremes (“detection”), as well as the extent to which such changes and the attendant changes in hazards are caused by anthropogenic emissions of greenhouse gases (“attribution”; e.g., AR6 Seneviratne *et al.* 2021).

It is naïve to assume that any recent extreme event is caused by human influences on the climate. Climate is about the statistical properties of weather over decades, not single events. Further, there are only about 130 years of reliable observational records that can be analyzed statistically. That brief interval does not begin to contain all the extreme events that the climate system can create on its own. Over geologic time the climate system has generated an (essentially) infinite variety of weather patterns and extremes that humans have never observed and thus are absent from the databases used to determine extreme statistics [see *Perils of short data records* below]. For that reason, attributing an extreme event unprecedented in the record requires assumptions about the magnitude of natural variations.

This chapter is concerned with detection of trends in extreme weather, while Chapter 8 considers causal attribution, with Section 8.4 specifically addressing extreme weather. If no trend is detected, then clearly there is no basis for attribution. But even where a trend is observed, attribution to human-caused warming does not necessarily follow.

This is especially true for precipitation events. The hydrological literature has long noted the phenomenon of Long-Term Persistence (LTP) in rainfall data (Hurst 1951, Cohn and Lins 2005, Markonis and Koutsoyiannis 2016). LTP has a formal mathematical definition, but it can be thought of as the presence of natural variations with strong autocorrelations that result in cycle-like behavior on long time scales. The presence of LTP requires long records to accurately estimate variability. Analysis of records that are short relative to the LTP scale will tend to underestimate variability, therefore overstating the significance of apparent trends and underestimating the likelihood of extreme events (Cohn and Lins 2005).

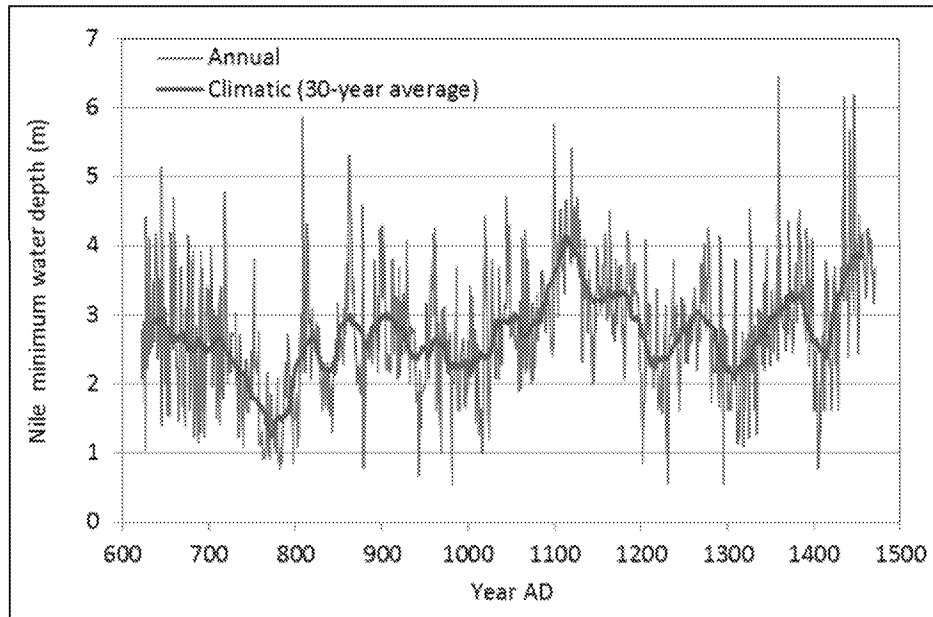


Figure 6.1.1: The annual minimum depth of the Nile River near Cairo over more than 650 years from 622 to 1284 A.D. The data, measured in meters, shows a characteristic pattern of year-to-year fluctuations around longer-term trends. Data from Koutsoyiannis (2013)

A good example of LTP is the eight-century long record of the annual minimum height of the Nile River observed at Roda Island in Cairo shown in Figure 6.1.1. The Nile River is fed by precipitation over a 4 million square mile drainage basin, an area equal to about one third of CONUS. Since human influences on the global climate were negligible before the 20th century, the century-scale variability of the thirty-year average is entirely natural; Egyptians of the seventh and eighth centuries would have been incorrect to assume that the worsening drought during that time was the “new normal.”

With these caveats in mind, we examine the evidence for changes in selected weather and climate extremes. A recurring theme is the wide gap between public perceptions and scientific evidence. It has become routine in media coverage, government and private sector discussions, and even in some academic literature to make generalized assertions that extreme weather of all types is getting worse due to GHGs and “climate change.” Yet expert assessments typically have not drawn such sweeping conclusions and instead have emphasized the difficulty both of identifying specific trends and establishing a causal connection with anthropogenic forcing.

In the sections to follow we provide excerpts from various IPCC and NCA assessment reports denoting the sources as follows:

SREX: The IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (2012)

AR6: The IPCC Sixth Assessment Report Working Group 1 (2021).

NCA4: The U.S. Climate Science Special Report of the Fourth National Climate Assessment (2017) Volume I.

NCA5: The U.S. Climate Science Special Report of the Fifth National Climate Assessment (2023) Volume I.

In the excerpts, *italics* are in the original whereas **boldface** emphasis has been added.

Additionally we present updated data series from standard government sources to provide up-to-date information through 2024 wherever possible.

6.2 Hurricanes and tropical cyclones

AR6 provides the following assessment of tropical cyclones (TCs; used here as a synonym for hurricanes):

AR6: There is *low confidence* in most reported long-term (multidecadal to centennial) trends in TC frequency or intensity-based metrics due to changes in the technology used to collect the best-track data. (IPCC, 2021 p. 1585)

AR6: It is *likely* that the global proportion of major (Category 3–5) tropical cyclone occurrence has increased over the last four decades . . . There is *low confidence* in long-term (multi-decadal to centennial) trends in the frequency of all-category tropical cyclones. (IPCC, 2023 SPM p. 9)

AR6: A subset of the best-track data corresponding to hurricanes that have directly impacted the United States since 1900 is considered to be reliable, and shows **no trend in the frequency of U.S. landfall events**. (IPCC 2021 p. 1585)

Since 1980, when satellite observations first fully covered the global oceans, we have confidence in the numbers of total global hurricanes and major hurricanes (Category 3 and higher). Figure 6.2.1 shows that on average, each year there are about 50 hurricanes, with about 25 reaching major hurricane status (Maue, 2025). There is substantial year-to-year and decadal variability, a weak decrease in the number of hurricanes, and a slight but insignificant increase in the number of major hurricanes. These two trends combine to create an overall increase in the proportion of major hurricanes.

Global hurricane statistics are dominated by the Northwest Pacific Ocean, which accounts for ~35 percent of total global hurricanes, whereas the Atlantic accounts for ~15 percent of global hurricanes (Colorado State University, 2025). Data in the Atlantic basin extends further back than in the other ocean basins and is most relevant to U.S. policy makers.

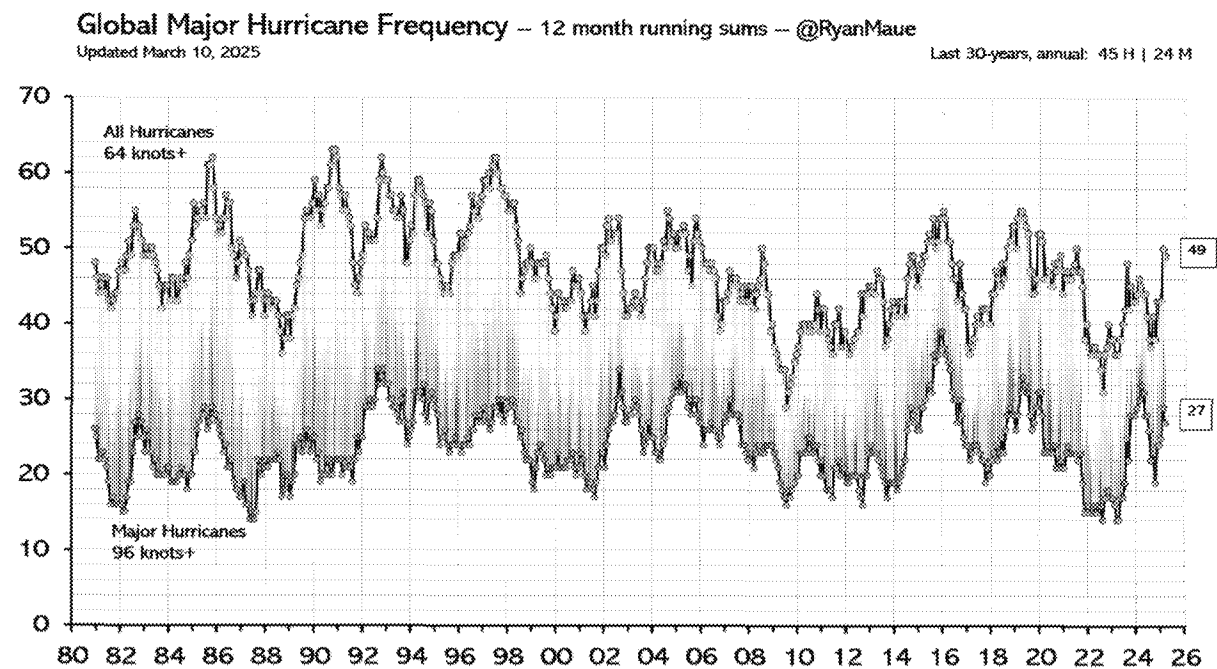


Figure 6.2.1: Global frequency of hurricanes and major hurricanes since 1980.

Figure 6.2.2 shows the frequency of Atlantic hurricanes and major hurricanes (Category 3 and higher) back to 1920. Data prior to 1965 (the onset of satellite observations in the Atlantic, shaded in blue) shows some undercounting, with data prior to 1920 showing substantial undercounting (Vecchi and Knutson, 2011). All measures of Atlantic hurricane activity show a significant increase since 1970. However, the period from 1971-1994 saw exceptionally low activity, with high activity (comparable to the past two decades, even with undercounting) also observed during the 1950's and 1960's, and even in the 1930's.

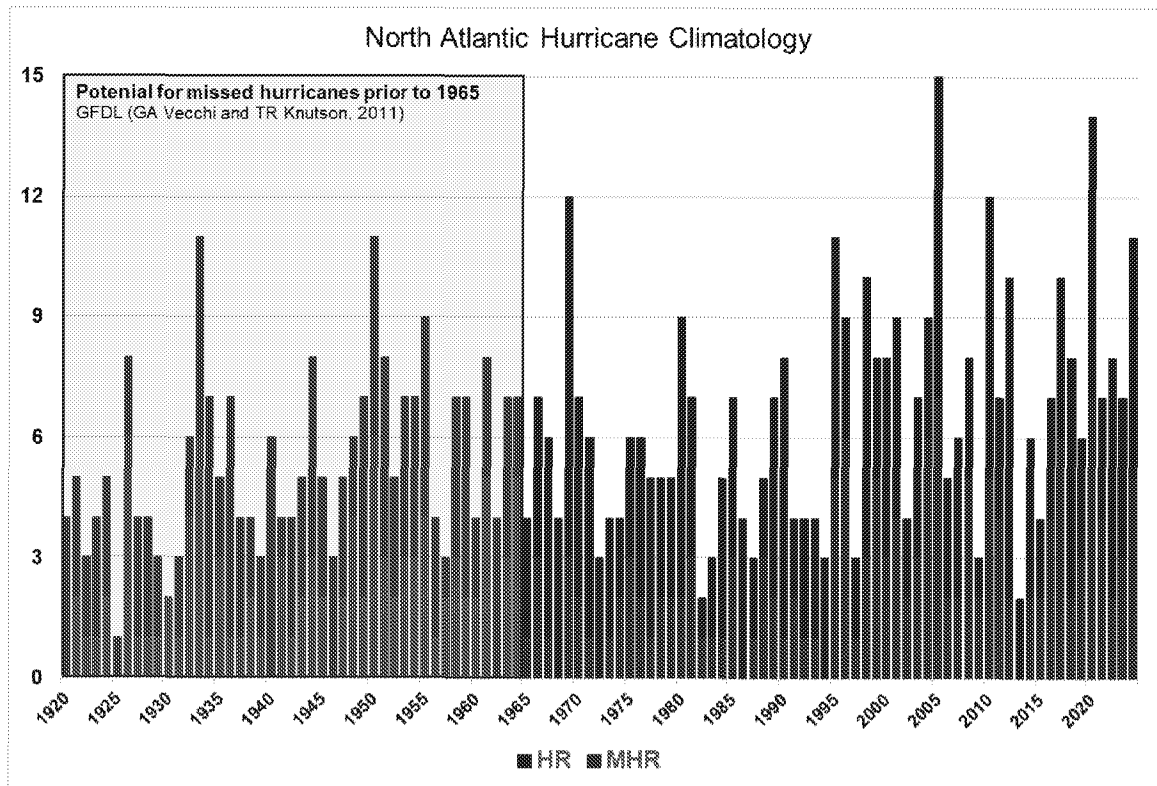


Figure 6.2.2: Atlantic frequency of hurricanes (HR) and major hurricanes (MHR) since 1920. Source National Hurricane Center (2024)

Figure 6.2.2 shows that Atlantic hurricanes vary strongly on decadal and multidecadal time scales. These variations are associated primarily with the Atlantic Multidecadal Oscillation (AMO), which is manifest in basin-wide sea surface temperature and sea level pressure fluctuations connected to large scale ocean circulation patterns. The AMO was in its warm phase during 1926-1970 and 1995-present, but in its cool phase during 1971-1994. It has its greatest impact on the number of major hurricanes (Category 3+), identified by Goldenberg *et al.* (2001) as associated with above normal SSTs and decreased vertical shear in the AMO warm phase (see also Bell and Chelliah, 2006; Klotzbach *et al.*, 2018).

Klotzbach *et al.* (2018) conducted a comprehensive evaluation of the landfalling hurricane data for the Continental U.S. since 1900. Figure 6.2.3 updates their analysis through 2024. While the largest numbers of landfalling hurricanes are from 2004, 2005 and 2020, there is no statistically significant trend since 1920. Figure 6.2.3 also shows the time series for major hurricane landfalls (Category 3-5). The largest year in the record is 2005, with 4 major hurricane landfalls. However, following 2005 there were no major hurricanes striking the U.S through 2016, the longest such period since 1920.

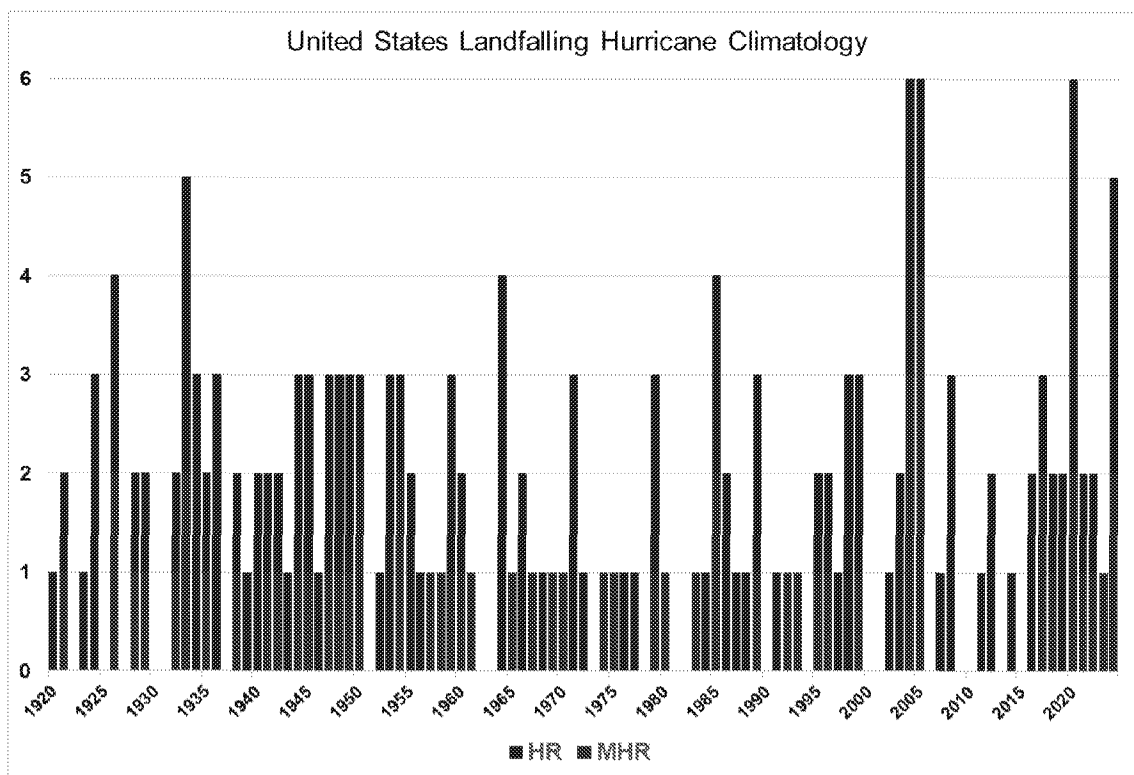


Figure 6.2.3: U.S. landfalling frequency of hurricanes (HR) and major hurricanes (MHR) since 1920. Source NOAA HRD(a) (2024)

Figure 6.2.3 shows substantial interannual to multidecadal variability in U.S. landfall activity. Klotzbach *et al.* (2018) examined how the landfall counts vary with ENSO (El Niño versus La Niña) and the warm versus cold phases of the Atlantic Multidecadal Oscillation (AMO).

Villarini *et al.* (2012) provide an analysis of U.S. hurricane landfalls back to 1878. While it is possible that some landfalls were missed in the late 19th century owing to sparsely populated regions on the Gulf Coast, it is remarkable that the highest year in the entire record is 1886, with 7 hurricane landfalls, when human influences on the climate were much smaller than they are today.

Table 6.2.1 shows the 10 strongest hurricanes (plus ties) to make U.S. landfall. Of the hurricanes that have made landfall with sustained winds greater than 150 mph, only one has occurred in the 21st century.

In summary, analyses of both global and regional variability and trends of hurricane activity provide the basis for detecting changes and understanding their causes. The relatively short historical record of hurricane activity, and the even shorter record from the satellite era, is not sufficient to assess whether recent hurricane activity is unusual relative to the background natural variability. Atlantic hurricane processes are influenced substantially by the natural modes of ocean circulation variability in the Atlantic, notably the Atlantic Multidecadal Oscillation. While it has long been hypothesized that a rising global sea surface temperature would cause an increase in hurricane intensity, identification of any significant trend in the hurricane data is hampered by a short data record and substantial natural variability.

Rank	Year	Landfall Wind (MPH)	Name
1	1935	185	"Labor Day"
2	1969	175	Camille
3	1992	165	Andrew
4	2018	160	Michael
5	1856	150	"Last Island"
5	1886	150	"Indianola"
5	1919	150	-----
5	1932	150	"Freeport"
5	2004	150	Charley
5	2020	150	Laura
5	2021	150	Ida
5	2022	150	Ian

Table 6.2.1 Strongest hurricanes to make landfall along the U.S. coast. Source (NOAA HRD(b), 2024)

6.3 Temperature extremes

The AR6 assessment focused on the period after 1950 and reported increasing trends in heatwave frequency and intensity. However, NCA4 noted that heatwave activity in the U.S. reached a peak in the 1930s (Figure 6.3.1).

AR6: It is *virtually certain* that hot extremes (including heatwaves) have become more frequent and more intense across most land regions since the 1950s, while cold extremes (including cold waves) have become less frequent and less severe (SPM, A3.1)

AR6: In North America, there is very robust evidence for a *very likely* increase in the intensity and frequency of hot extremes and decrease in the intensity and frequency of cold extremes for the whole continent, though there are substantial spatial and seasonal variations in the trends. Minimum temperatures display warming consistently across the continent, while there are more contrasting trends in the annual maximum daily temperatures in parts of the USA. (Chapter 11, p 1550)

NCA4: Changes in warm extremes are more nuanced than changes in cold extremes. For instance, the warmest daily temperature of the year **increased** in some parts of the West over the past century, but there were **decreases** in almost all locations east of the Rocky Mountains. In fact, all eastern regions experienced a net **decrease**, most notably the Midwest (about 2.2°F [1.2°C]) and the Southeast (roughly 1.5°F [0.8°C]). (pp. 190-191)

NCA4: Since the mid-1960s, there has been only a very slight increase in the warmest daily temperature of the year (amidst large interannual variability). Heat waves (6-day periods with a maximum temperature above the 90th percentile for 1961–1990) increased in frequency until the mid-1930s, became considerably less common through the mid-1960s, and increased in frequency again thereafter. As with warm daily temperatures, **heat wave magnitude reached a maximum in the 1930s.** (pp. 190-191)

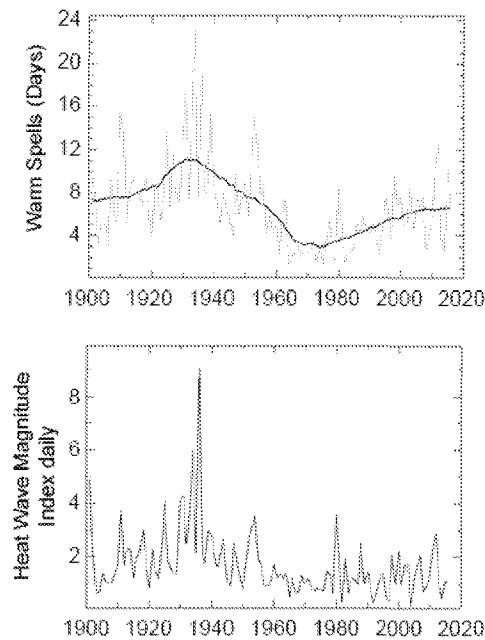


Figure 6.3.1: U.S. Heat waves since 1900. Source: NCA4 Figure 6.4

6.3.1 *Temperatures in the U.S. are becoming less extreme*

Daily maximum temperatures in the warm season (Tmax, May-Sep) and daily minimum temperatures in the cold season (Tmin, Dec-Mar) are available beginning in Dec 1898 (126 years). The dataset consists of 1,211 CONUS stations designated as United States Historical Climate Network or USHCN stations (see Figure 6.3.2; Quinlan *et al.* 1987, Karl *et al.* 1990). These stations were selected by NOAA as having the fewest problematic issues with gaps, station moves, and instrument changes. Where gaps still exist, nearby stations (bias-corrected) were merged so that the median volume of data available for a station is 98%. Although there are certainly errors in the dataset, including unresolved spurious warming due to UHI effects that especially bias Tmin records, this data set is sufficiently accurate for assessing trends in Tmax heat extremes.

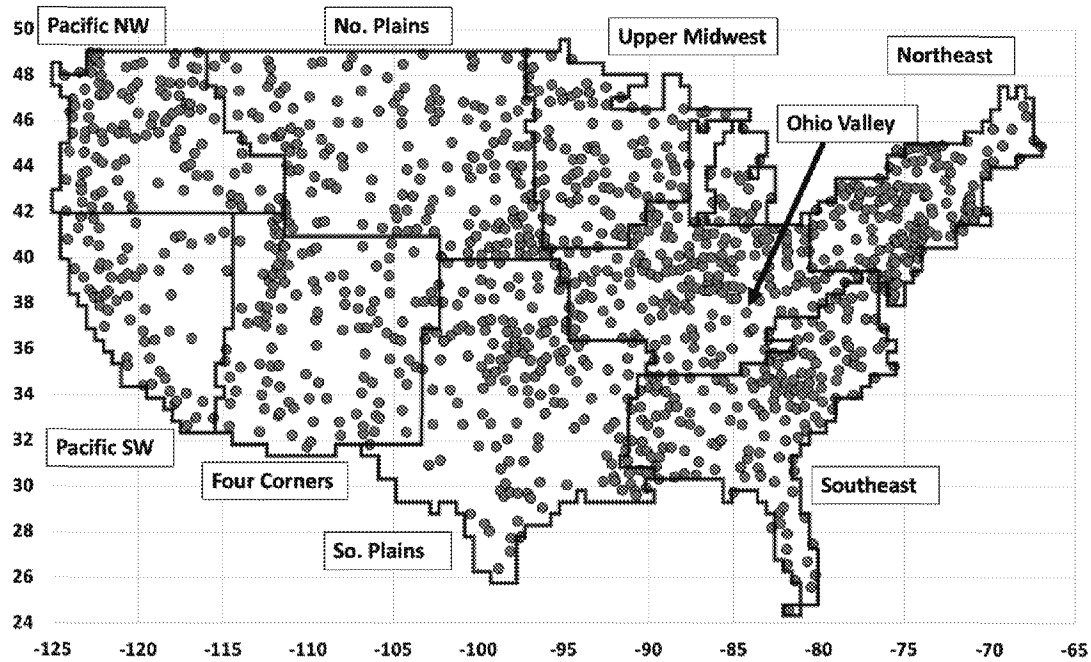


Figure 6.3.2 Locations of USHCN temperature stations. Source: USHCN.

We begin with the question of whether the occurrence of daily record high or low temperatures has changed since Dec 1898. Each warm-season has 153 days (1 May to 30 Sep) and each cold-season has 122 days (1 Dec to 31 Mar). For each station and day, we calculated the year in which the record highest (lowest) temperature occurred. With 126 years of observations, if there were no temperature trends over time, the expected number of records for Tmax would be 1.21 ($=153/126$) per station per year and for Tmin 0.96 ($=122/126$) per station per year.

Figure 6.3.3 shows the observed distribution in time of the occurrence of these extreme events. There is a common feature in many metrics of warm-season extremes in the CONUS - the exceptional heat of the 1920s and especially the 1930s, peaking in 1936. On a per-station average, 60 percent of the Tmax records and 59 percent of the Tmin records occurred in the first half of the period (1899-1961).

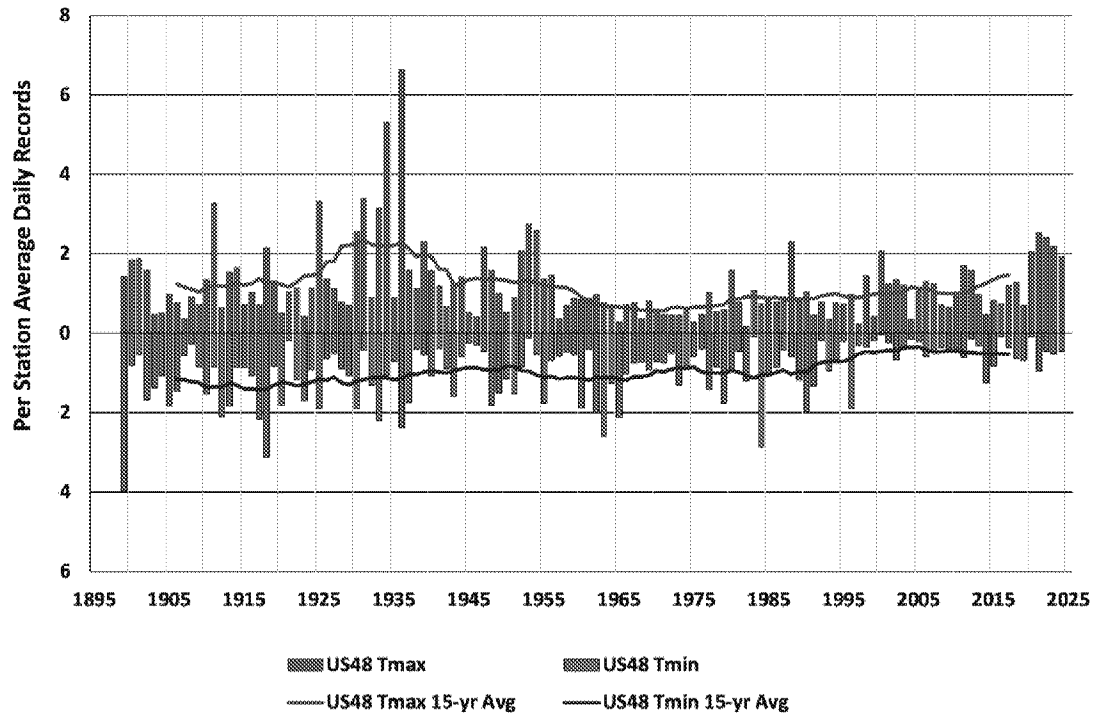


Figure 6.3.3 Number of daily record High (red) and Low (blue) temperatures for warm and cold seasons in the CONUS. The lines represent the 15-year running, centered average. Source: 1,211 USHCN stations supplemented as needed to achieve a minimum of 92 percent of observations in the 126-year period since Dec 1898. US48: contiguous U.S. states. Tmax: maximum temperature. Tmin: minimum temperature.

On the cold side, the Valentine’s Day Arctic outbreak in Feb 1899 stands as the most extensive cold extreme experienced by CONUS, with 1917 in 2nd place. The frequency of cold records has declined, especially over the last quarter of the period in which only 13 percent of the extreme cold events were measured. In contrast, 25 percent of the extreme Tmax records were achieved in the last quarter, in accordance with statistical expectations. These general features have been noted in past assessments (see above, IPCC AR6, NCA4). Combining the two histories, the overall reduction in numbers of both cold and hot extremes over the past century indicates a climate less prone to extremes.

This pattern is also shown in Figure 6.3.4. For each station and for each year the hottest warm season and coldest cold-season temperatures were calculated. Then the differences between these were computed by station and geographically-averaged over all stations, thus yielding an annual measure of the expected range of local extreme temperatures for each year. Figure 6.3.4 shows the 15-year trailing average of this measure, which has clearly declined over the past century.

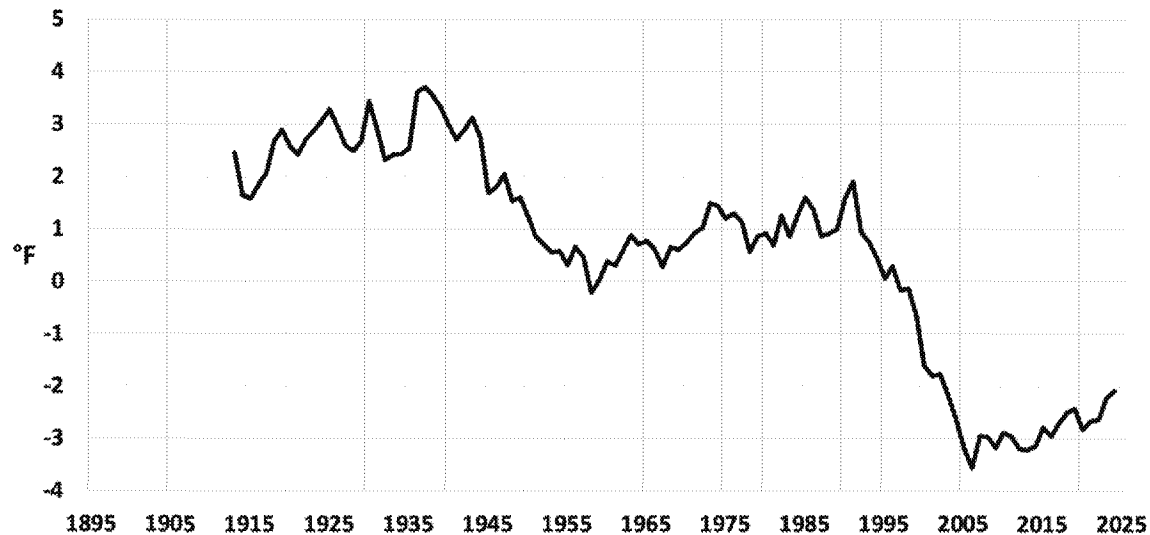


Figure 6.3.4. 15-year trailing average of the difference each year of each station's hottest warm-season Tmax and coldest cold-season Tmin relative to the long-term average. Source: Author analysis of USHCN data.

The average difference for each station between the hottest summer Tmax and coldest winter Tmin has declined by about 5°F in the past 126 years. The decline is due mostly to warmer winter Tmin, but a decline in summer Tmax is also a factor. The rise in Tmin has been strongly related to the growing presence of manufactured surfaces around the weather stations over the last 100+ years (the so-called urban heat island effect; Section 3.3 and Spencer *et al.* 2025).

In summary, while temperature extremes are regularly experienced in the U.S. and attract a great deal of media attention, long term records show the U.S. climate has become less extreme over time (milder) when measured by the range between warm season maxima and cold season minima.

6.3.2 Exceedances of a heat threshold

Under the heading of “The Risk of Temperature Extremes is Changing”, the most recent U.S. National Climate Assessment report (NCA5) notes the increase in a threshold metric of number of days at or above 95°F, stating,

The western U.S. has been particularly affected by extreme heat since the 1980s ..., experiencing a larger increase in days over 95°F, as would be expected given the greater warming in that region relative to the eastern US. Several major heatwaves have affected the U.S. since 2018, including a record-shattering event in the Pacific Northwest in 2021.

Are the occurrences of 95°F days changing? In a climate as varied as that of CONUS, threshold statistics can be misleading. A region with many stations that have near 95°F Tmax average temperatures in the summer might see large swings in the metric when only small changes in average temperature occur. Elsewhere with stations that either rarely or virtually always achieve 95°F Tmax temperatures, a small change will not have much impact on the results.

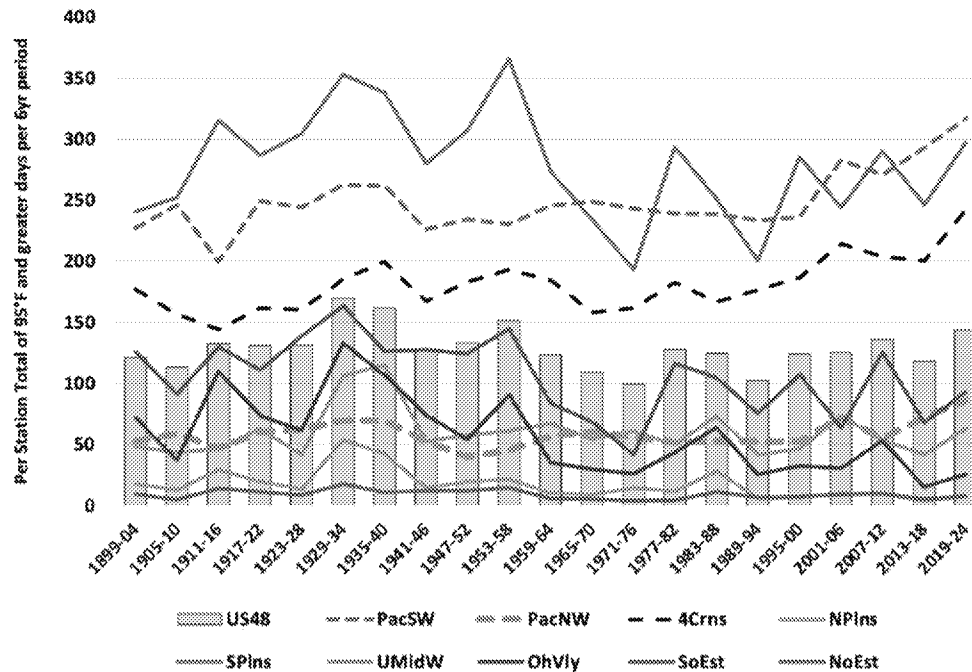


Figure 6.3.5. Total number of days $\geq 95^{\circ}\text{F}$ in 6-yr periods, U.S. 48 (bars) and regions (lines). A 6-year period is used as this evenly divides the 126-year record. US48: contiguous U.S. states. See Figure 6.3.2 for region names. Source: Author analysis of USHCN data.

In the past 126 years, the average CONUS station experienced 129 days exceeding 95°C per 6-yr period, but the regional values range from 278 in the Southern Plains to 9 in the Northeast. Thus, such threshold analyses must be interpreted with caution. Figure 6.3.5 shows that only three of the nine regions, all in the West, have experienced upward trends in the number of 95°F or hotter days (dashed lines). The CONUS as a whole has not, and the other six regions have experienced declines.

The Pacific NW heatwave of 2021 referenced in the NCA5 quote will be examined more closely in Section 8.6.1. The evidence indicates that it was a single, unprecedented event in the record, not part of a pattern of increasing extreme heat. For example, the 5-day average tropospheric grid-point temperature anomaly over the Pacific NW during that event was $+10.8^{\circ}\text{C}$, the most extreme Northern Hemisphere grid point summer anomaly in the 46 years from over 4 million grid values. In contrast, the global temperature anomaly during that time was virtually zero ($+0.03^{\circ}\text{C}$, Mass *et al.* 2024).

The NCA5 heading “The Risk of Temperature Extremes is Changing” suggests pervasive positive trends are now being observed in threshold temperatures, but that is not evident in the figures above.

6.3.3 Heatwaves

Heatwaves (consecutive days that exceed an extreme threshold) have a greater societal impact than a single daily record temperature. We measure “Heatwave Days” here as the count of all days in May-Sep each year that exceed the 90th percentile for that day and that lie within a period of at least six consecutive days. This is equivalent to the method used in NCA4, except that the reference period here is the entire record 1899-2024 while NCA4 truncated the reference period to 1961-1990, which was a cool interval. That truncation boosts positive results (days exceeding the 90th percentile) in years warmer than the reference period, especially starting in 1960 and moving to the present (see Figure 6.3.6 and discussion below).

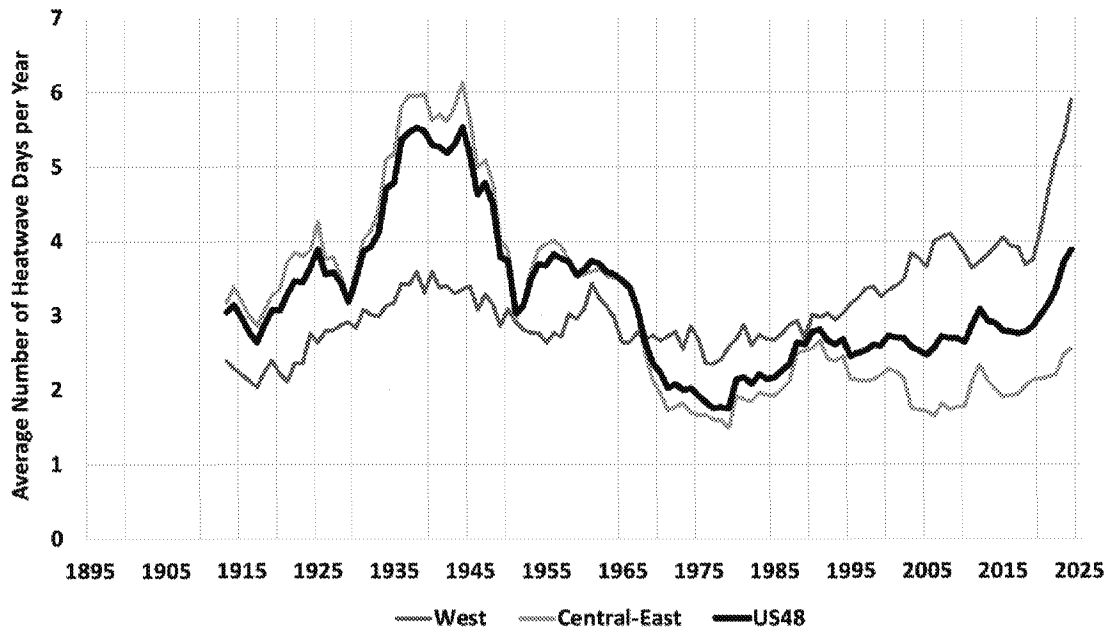


Figure 6.3.6 15-year trailing average of number of heatwave days per year per station in the CONUS (black line) and two regions: West (red), Central-east (green).

Figure 6.3.6 indicates that there are regional variations in heatwave activity. The excessive heat of the first half of the 20th century occurred primarily in the eastern two-thirds of the nation, while the West has seen a recent increase of heatwave days (NCA5). This indicates that the background warm season circulation favored heatwaves in the eastern portions of the country in the first half of the 20th century, but in the 21st century the patterns have favored heatwaves in the West. For CONUS as a whole, heatwaves are no more common today than they were a century ago, consistent with the upper panel of our Figure 6.4.1 taken from NCA4.

This metric varies significantly with region. The four northern regions (Pacific NW, Northern Plains, Upper Midwest, and Northeast) on average experience 15 to 27 heatwave days per 15-year period. In contrast, the five southern regions (Pacific Southwest, 4-Corners, Southern Plains, Ohio Valley and Southeast) see 37 to 54 such days, essentially twice as many. This suggests the summer circulation pattern is more prone to stationary events in the southern regions while transient systems in the northern regions are more common and thus cut short these potentially longer events.

The analysis of heatwaves is an example of why it is important to consider complete datasets and appropriate metrics. The NCA5 directs readers to the website [[HYPERLINK "https://www.globalchange.gov/indicators/heat-waves"](https://www.globalchange.gov/indicators/heat-waves)] (USGCRP 2023) to view a figure showing the number of urban heatwaves by decade from the 1960s, which we reproduce as Figure 6.3.7.

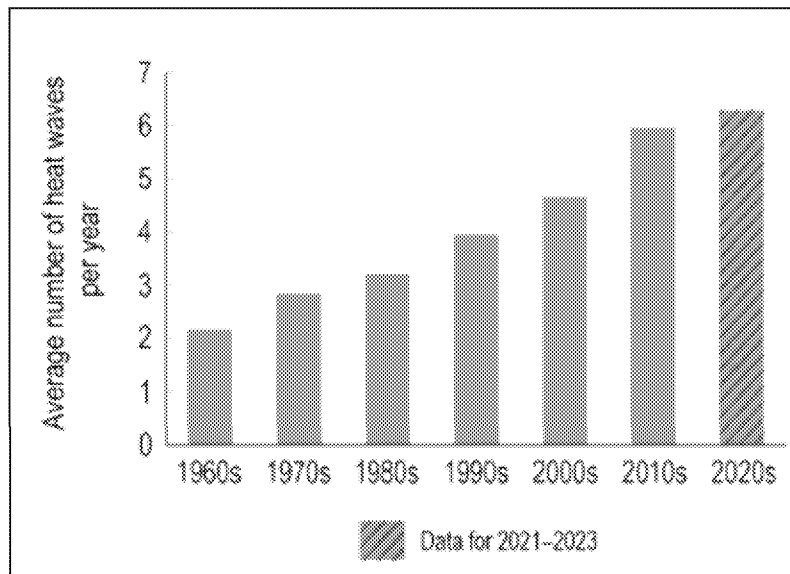


Figure 6.3.7: Average number of urban heatwaves per year for 50 large U.S. metropolitan areas, a misleading metric for reasons explained in the text. From [[HYPERLINK "https://www.globalchange.gov/indicators/heat-waves"](https://www.globalchange.gov/indicators/heat-waves)] (accessed May 22, 2025).

The figure shows a monotonic increase in each decade from two occurrences per year in the 1960s to six in the 2020s. The definition of a heatwave used is an unusual but practical measure of human discomfort - a period of at least 2 consecutive days when the *minimum* apparent temperature (combination of temperature and humidity) exceeds the 85th percentile. Note too, the dataset is limited to the 50 largest U.S. cities.

Given the unusual heatwave definition and urban focus, these increasing values since 1960 presented in USGCRP (2023) are not informative about long term trends or the influence of GHG emissions for at least two reasons. First, as shown in Figures 6.3.1 and 6.3.6, the 1960s was the coldest decade and 1970s the second coldest decade since the 1910's, so this starting date preconditions the time series to show increases. Second, post-1960 urbanization in these cities is a major factor in the rise of T_{min} relative to co-located T_{max} and relative to T_{min} at nearby rural stations. This does not dismiss the real rise in nighttime temperatures in major U. S. cities and the societal impacts associated with these changes. However, we note for a variety of reasons that summer T_{max} (especially in rural areas) is a better metric for detecting changes in heatwaves influenced by changes in the background climate due, for example, to increasing GHGs (Christy *et al.* 2009). For CONUS as a whole, the evidence in this section suggests GHG emissions have had little-to-no effect on heatwaves against the background of urbanization and natural climate variability.

6.4 Extreme precipitation

AR6 assessed that an increase in heavy precipitation has been observed in data starting in the 1950s.

AR6: The frequency and intensity of **heavy precipitation events have increased** since the 1950s over most land area for which observational data are sufficient for trend analysis (high confidence). (SPM A3.2)

AR6: In North America, there is robust evidence that the **magnitude and intensity of extreme precipitation has *very likely* increased** since the 1950s. Both [one-day maxima] and [5-day maxima] have significantly increased in North America during 1950-2018. (Chapter 11, p. 1560)

The U.S. National Climate Assessments (NCA4, NCA5) have highlighted an increase in the occurrence of the heaviest precipitation events (defined in different ways) primarily in the eastern half of CONUS, especially the Northeast, when starting the analysis in either 1901 or 1958. Interestingly, the regional variations indicate that the largest increases in extreme precipitation events are in the Northeast and the smallest in the West, a pattern counter to the changes in temperature extremes (Figure 6.3.6).

McKittrick and Christy (2019) examined long-term and consistent station observations of extreme daily precipitation to test some of these NCA claims for the Southeast and West Coast using a trend model with a non-parametric variance estimator robust to the complex autocorrelation properties of precipitation data. When the time series were extended back in time (as far as 1872 in some cases) or started later (1978), there were no significant trends for either region.

These findings have been updated for this report (McKittrick and Christy 2025) with similarly constructed observations from 29 stations on the CONUS Pacific Coast (1893ff from San Diego CA to Blaine WA) and 24 stations in the humid Southeast (1872ff from Austin TX to Washington DC), also adding 27 stations in the Northeast (1888ff from Buffalo NY to Eastport ME). The locations are shown in Figure 6.4.1. The stations were selected based on availability of long-term high-quality records. The regions are each associated with important features of extreme precipitation behavior: the Pacific coast is associated with landfalling atmospheric rivers for which AR6 cites evidence of increasing activity since 1948 with further increases expected as the world warms (AR6 8.3.2.8.2); the NCA report indicates that the Northeast has experienced the greatest increase in extreme events, and the Southeast is also a place noted in the NCAs as having increased extreme events.

The results of applying the analysis of McKittrick and Christy (2019) were as follows for each region, then followed by further explanation.

Pacific Coast heavy rainfall events

- The average precipitation trend is statistically significant (downwards) in Astoria OR; insignificant elsewhere.
- The trend in rainfall variance is positive and significant in Big Sur CA; insignificant elsewhere.
- The trend in daily maximum precipitation is positive and significant in Aberdeen WA and Big Sur CA and negative and significant in Newport OR (insignificant elsewhere).
- Averaged over all stations in the region, none of these three trend parameters is statistically significant.

The Pacific Coast receives considerable precipitation from Atmospheric River (AR) events which often last more than a day or two (e.g., Gershunov *et al.* 2017, Pan *et al.* 2024). The worst series of such events in recent history was the so-called ARkStorm that occurred during December 1861 and January 1862; it dumped nearly 10 feet of rain in parts of California and submerged the entire Central Valley for weeks under as much as 15 feet of water (Brewer 1930, Null and Hulbert 2007). Additionally, Paleoclimate research has found six megastorms more severe than 1861–1862 in California during the last 1800 years, occurring at intervals of 300 years or so (Porter *et al.* 2011).



Figure 6.4.1: Locations of precipitation monitoring stations used in this report. Orange: Pacific coast. Blue: Northeast. Green: Southeast. Data from McKittrick and Christy (2025).

We examine occurrences of 5-day deluges as follows. Taking the Pacific coast as an example, a 130-year span contains 26 5-year intervals. At each location we computed the 5-day precipitation totals throughout the year and selected the 26 highest values across the sample. A single year might have more than one of the 26 heaviest. Each of those can be thought of as 1-in-5yr events. If there are no trends in precipitation, then the total number of these events across all stations should be evenly spread over the years. In Fig. 6.4.2 we show the distribution in time of these events for the Pacific coast. The deluges associated with the massive 1997-98 El Niño event are readily apparent. While erratic, as is typical of such precipitation metrics, there is no indication of a tendency to become more frequent over time.

Southeast heavy rainfall events

- The trend in average precipitation is positive and statistically significant in Mobile AL and Quitman GA but insignificant elsewhere.
- The trend in rainfall variance is positive and significant in Mobile AL but insignificant elsewhere.
- The trend in daily maximum precipitation is positive and significant in Vicksburg MS and Norfolk VA but insignificant elsewhere.
- Averaged over all stations in the region none of these three trend parameters is statistically significant

Figure 6.4.3 is analogous to Figure 6.4.2 for the last 150 years in the Southeast humid zone. The temporal pattern of 5-day totals of the 1-in-5yr heavy events is generally unremarkable, though a cluster of higher values appears in 1995 to 2019. The increase in those years is due largely to the 4 northeastern-most stations of Wilmington NC, Weldon NC, Washington DC, and Norfolk VA. This confirms the pattern indicated in NCA4 and NCA5 -- an increasing frequency of heavy events due to a temporal clustering of tropical storms from eastern NC to Maine discussed below. Otherwise, the remaining 20 stations show an unremarkable temporal distribution of heavy events.

BOX: Perils of short data records

San Francisco provides a good case study of the limitation of using short historical samples to characterize natural variability of extreme events. Suppose we use a 130-year sample of daily San Francisco precipitation from 1895 to 2024 and we look for 3-day, 5-day, 14-day and 30-day rainfall records. The results are as shown in Table 7.2.

Event	Record (inches)	Year
3-day	6.94	2023
5-day	8.55	2023
14-day	12.62	2023
30-day	18.93	1998

Table 6.2: Extreme rainfall records, San Francisco, 1895-2024.

The records all cluster in the more recent years. 2023 appears to be an exceptional year and since it is near the end of the sample, it might suggest that the climate has shifted into a more hazardous state, perhaps because of human influences. [Note “2023” indicates the event occurred in the water-year of Aug 2022 to Jul 2023.]

But the picture is very different if we use a sample that begins 45 years earlier, in 1850. Table 6.3 shows that the record-setting events all happened in the 1860s. Furthermore 2023 is now not even in 2nd place but falls to 3rd or 4th place. And comparing the records of the two charts shows the extreme precipitation events in 1862 and 1867 involved considerably more rainfall than the 1998 and 2023 events, with 14- and 30-day totals about 50 percent higher.

Event	Record (inches)	Year	Rank of 130-yr extreme listed in Table 6.2
3-day	8.85	1867	3
5-day	9.80	1867	3
14-day	19.05	1862	4
30-day	28.25	1862	2

Table 6.3: Extreme rainfall records, San Francisco, 1850-2024.

The range of natural variability is made even more remarkable when paleoclimate evidence is examined. Porter *et al.* (2011) discovered that in the past 1,800 years at least six megastorms were more intense than the devastating 1861-62 ARkStorm that struck the region. Evidently such extreme events, “unprecedented” in our 1895-2024 sample, have impacted the region about every 300 years, though not since 1895.

This example illustrates the limitations of using relatively short climate periods (~130 years) to assess the character and range of natural variability in general and of extreme events in particular. Accurate representation of the full range of natural variability is necessary for any attribution analyses (Section 8.6). Infrastructure planners, emergency management institutions and attribution scientists would understand the significant mischaracterization of the magnitude of a future extreme if based only on the last 130 years. In this case, a single time-sample of 130 years provides an underestimation of the extreme value by up to 50 percent determined when adding only 45 more years of observations. Compared to millennial-scale paleoclimate evidence, an even greater underestimation would occur. An important lesson is that the climate can deliver great surprises on its own, even without human influences.

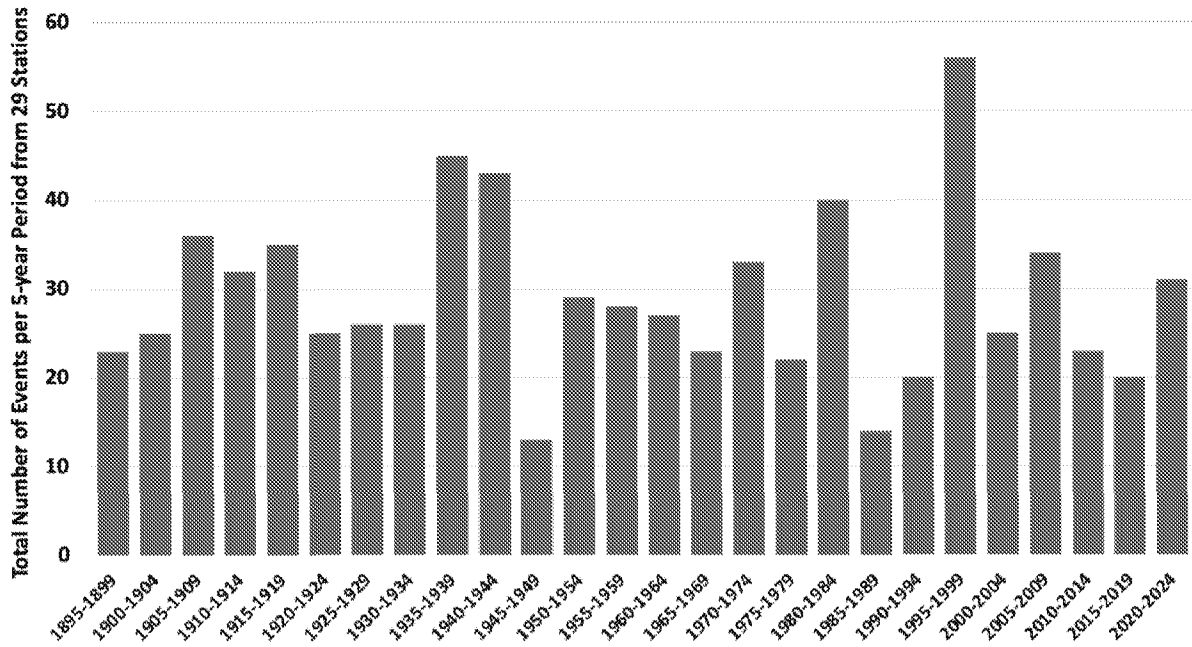


Figure 6.4.2. The time distribution by 5-year periods of the 26 heaviest (1-in-5 yr) occurrences for 29 stations on the Pacific coast.

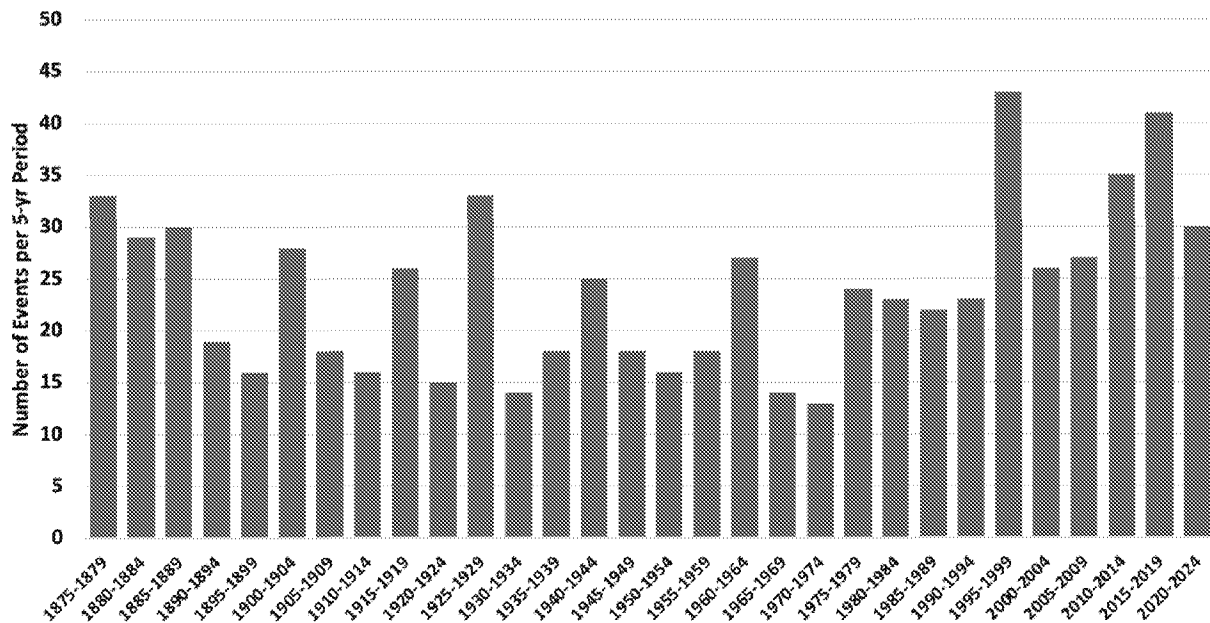


Figure 6.4.3. As in Fig. 6.4.2 but for the heaviest 30 (1-in-5yr) events for 24 stations in the humid Southeast from Austin TX to Washington DC in 5-year bins for 1875-2024.

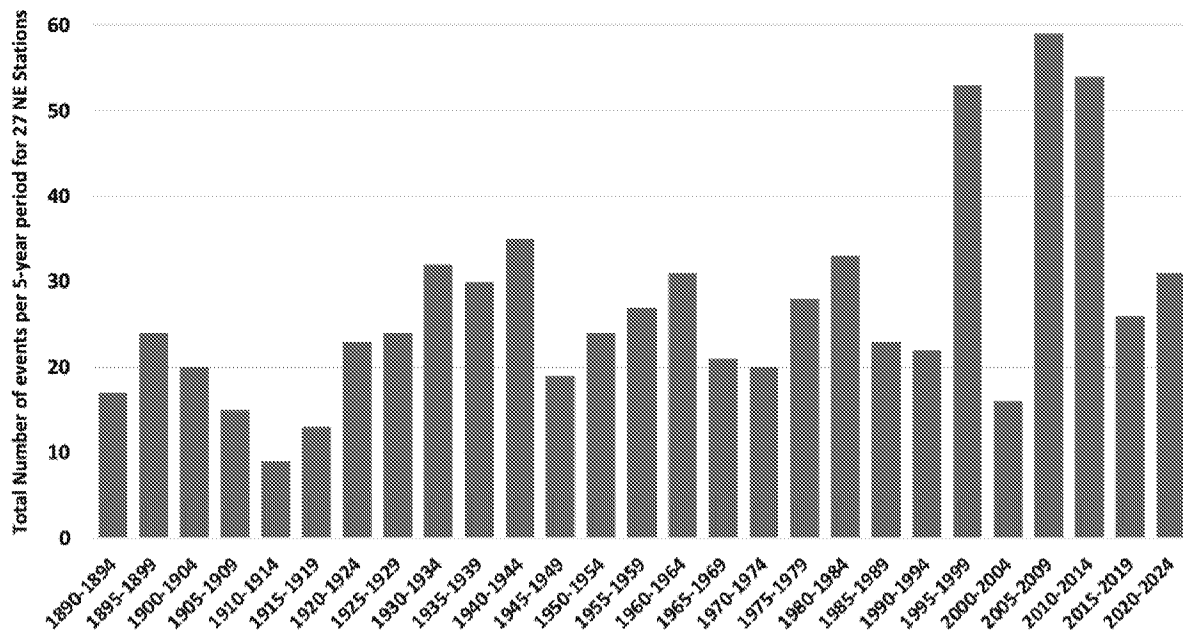


Figure 6.4.4. As in Fig. 6.4.2 but for the heaviest 27 (1-in-5yr) 3-day precipitation events for 27 Northeast stations from NY to ME, including Montreal.

Northeast heavy rainfall events

- The trend in average precipitation is positive and statistically significant in 12 of 27 locations and also in the regional average.
- The trend in rainfall variance is positive and significant in Portland ME, Albany NY, Buffalo NY and Eastport ME but insignificant elsewhere.
- The trend in daily maximum precipitation is positive and significant in Portland ME, Gardiner ME and Eastport ME but insignificant elsewhere.
- When averaged over all stations in the region, there is no statistically significant trend in either the precipitation variance or maximum

Fig. 6.4.4 is analogous to Figure 6.4.2 for the last 135 years in 27 stations in the Northeast (including Montreal Canada). We use 3-day totals here as this produced the largest temporal variations in time. In this region, 77 percent of events occur during June to October and are dominated by incursions of hurricanes, tropical storms, or tropical storms that transition to extratropical systems. According to NCA4 and NCA5 this region experienced the largest increases in extreme events, so it merits a closer examination.

There is a noticeable clustering of extreme events from 1995 to 2014. Howarth *et al.* (2019) examined a similar region as in Fig. 6.4.4 that includes PA and NJ and reported significant differences in various precipitation extremes between two 18-year periods, 1979-96 and 1997-2014. That included a 317 percent increase in 24-hr events exceeding 6 inches, while we find a 58 percent increase over the same years. However, Figure 6.4.4 shows that frequency drops sharply after 2014, returning to the long-term average in the subsequent 5-year intervals, again illustrating the perils of drawing conclusions from short-term trends in highly variable metrics.

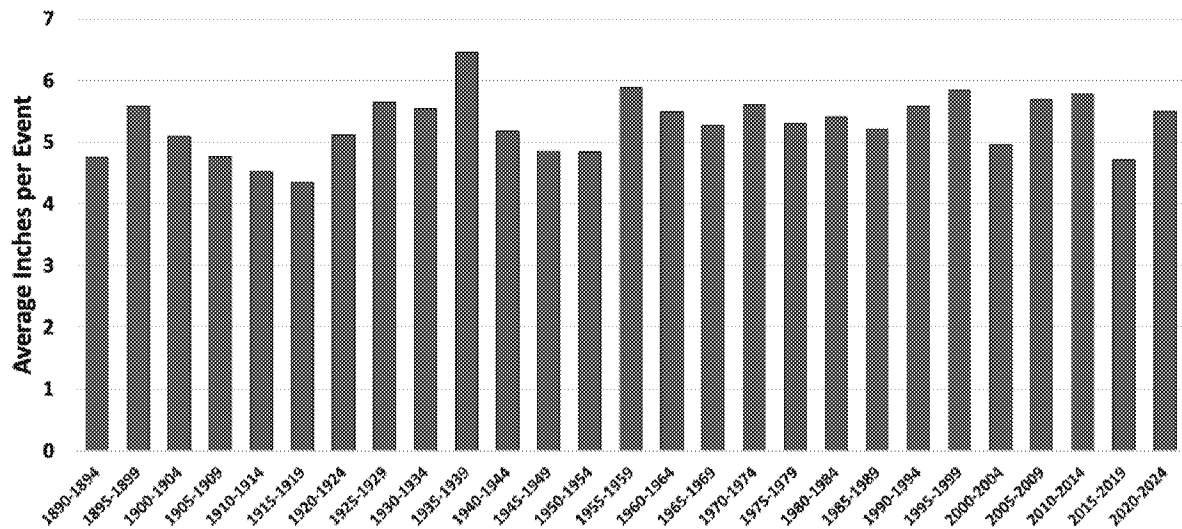


Figure 6.4.5. Average amount of precipitation falling in the 1-in-5yr events for the NE stations.

The high percentage increase in the Howarth *et al.* sample is associated with small numbers at relatively few locations: there were only 6 in the first period and 25 in the second across 58 stations. Most of the stations did not record such an event. If there is a region-wide increase in heavy events, it should be seen in the average across all stations. Figure 6.4.5 shows the average precipitation in the 1-in-5 yr events across the NE. The trend is only +0.04 inches/decade. The highest amount, 1935-39, includes the Great New England Hurricane of 1938, one of the rare major (Category 3 or higher) hurricanes to strike the region. The results in Figs. 6.4.4 and 6.4.5 thus suggest that though there was a surge in the number of events at a few locations during the 1995 to 2014 interval, there was no regional pattern and the change did not persist beyond 2014.

Jong *et al.* (2024) document the increase of tropical influences on precipitation events in the Northeast since 1959 and concluded “The autumn extreme precipitation trend over the Northeast U.S. is primarily attributed to tropical cyclone-related events since the 1990s.” The question then becomes: “Was the temporal clustering of tropical systems in 1997-2014 which affected the Northeast a response to increasing GHGs?” Jong *et al.* examined CMIP-6 model output which suggests that there will be fewer such systems in the 21st century but that the intensity of the rainfall events might increase. This conjecture is not seen in Fig. 6.4.5 where the amount-per-event has remained steady over the 135-year period.

There is some evidence to indicate the heaviest rainfall events might be redistributed due to the impact of urban infrastructure on the local weather (e.g., Pielke Sr. *et al.* 2011, Zhang *et al.* 2018, Yang *et al.* 2024). Yang *et al.* state “Cities that experience compact development tend to witness larger increases in extreme rainfall frequency over downtown than their rural surroundings, while the anomalies in extreme rainfall frequency diminish for cities with dispersed development.” While this is an important insight to consider, the effect on the specific stations used in this analysis is unknown, or at least not detectable in Fig. 6.4.5.

In summary, some U.S. regions show short-duration increases in extreme precipitation events, consistent with natural variability. But analysis of long term, nationwide historical records that considers the autocorrelation properties of precipitation data does not support the claim that extreme short-duration rainfall events are becoming more frequent or intense.

6.5 Tornadoes

AR6 assesses tornado trends in the U.S. as follows:

[O]bservational trends in tornadoes, hail, and lightning associated with severe convective storms are not robustly detected due to insufficient coverage of the long-term observations. There is *medium confidence* that the mean annual number of tornadoes in the USA has remained relatively constant. (Chapter 11, section 11.7.3, p. 1594)

The monitoring of weak tornadoes has changed over time. The growth of rural populations and the increasing ability to take video with hand-held devices has led to more frequent reports of weak tornadoes that produce minimal damage. In contrast, strong to violent tornadoes have been observed more consistently over time. Note that tornado strength is measured by the damage it produces, not by the visual appearance of the funnel. Limited real-time observational capabilities in earlier decades did not prevent identification because strong to violent tornadoes leave much more damage which will be assessed later even if the tornado itself was not observed. Since statistics began in 1950, there has been a substantial decrease (by about 50%) in the number of strong to violent tornadoes as shown in Fig. 6.5.1a.

To summarize, there is a noticeable downward trend in the number of severe tornadoes in the U.S. since 1950. After 1990 the number of weak tornadoes in the U.S. has remained roughly constant; data before that are incomplete due to limited monitoring.

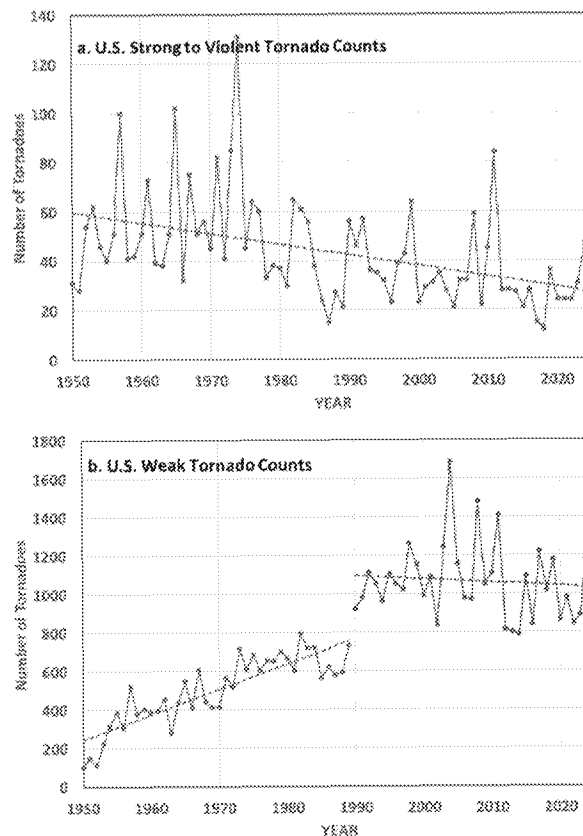


Figure 6.5.1. Annual U.S. tornado counts for (a) strong to violent tornadoes (EF3 to EF5), and (b) weak tornadoes (EF0 to EF2). Based upon NOAA Storms